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COVER: Rock Ptarmigan (*Lagopus muta townsendi*) on Amchitka Island, Alaska, in late May to very early June. Male Rock Ptarmigan on mainland Alaska and northern Canada during this same period are mostly white, a difference that has been used to describe subspecies of Rock Ptarmigan. See the article in this issue by Clait Braun *et al.*, pages 49–55. Photo: Steve Ebbert, 10 June 2015.

The Canadian Field-Naturalist

Characteristics of Wolverine (*Gulo gulo*) dens in the lowland boreal forest of north-central Alberta

Michael E. Jokinen[1,*], Shevenell M. Webb[2], Douglas L. Manzer[3], and Robert B. Anderson[3]

[1]Alberta Conservation Association, 817-4th Avenue South, Lethbridge, Alberta T1J 0P6 Canada
[2]Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, Maine 04401 USA
[3]Alberta Conservation Association, P.O. Box 1139 Provincial Building, Blairmore, Alberta T0K 0E0 Canada
[*]Corresponding author: mike.jokinen@ab-conservation.com

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Abstract

We investigated Wolverine (*Gulo gulo*) denning ecology in the boreal forest of northern Alberta. During winters 2015/2016 and 2016/2017, we used live traps to capture four female Wolverines and fitted them with global positioning system (GPS) collars programmed to take a location every two hours. We determined reproductive status at capture and GPS location data were used to identify den sites. One female denned in one of the two years, one female denned in two consecutive years, and two females did not den during the study. Seven of the eight Wolverine den sites were in mature or old Black Spruce (*Picea mariana*) stands, where dens consisted of a hollow, moss-covered mound originating from a partially uplifted root mass caused by a leaning or fallen tree. One den was located under decayed logging debris with an overstorey dominated by dense deciduous regeneration. Maximum snow depth recorded (December–March) at weather stations in the study area was 32–51 cm. Spring snow coverage was scarce in our study area (<1%) and always associated with ice cover on lakes and large ponds; mean distance from dens to nearest spring snow coverage was 15.19 km (SD = 2.73, n = 8). Female Wolverines appear to be using locally-available denning structures in the lowland boreal forest, despite a lack of deep snow, persistent spring snow cover, or large boulders documented in other studies.

Key words: Alberta; boreal forest; den; lowlands; snow; Wolverine

Introduction

Wolverines (*Gulo gulo*) are well adapted to cold, snowy environments with their compact body, large paws, dense, frost-resistant fur, and capacity to store significant body fat (Banci 1994). Because Wolverines give birth in winter, females must find suitable den sites that are protected from predators, disturbance, cold temperatures, and melting spring snow (Magoun and Copeland 1998). Most verified Wolverine dens were under 1–5 m of snow (Pulliainen 1968; Magoun and Copeland 1998), suggesting that a deep snowpack offers important benefits throughout the denning season (Magoun and Copeland 1998). The majority of Wolverine den locations documented around the world (n = 562 dens) overlapped areas with persistent spring snow; a small subset of dens that were outside this mapped area of persistent spring snow cover (hereafter, the spring snow coverage) were visited and later confirmed to be snow dens (Copeland *et al.* 2010).

Deep snow and/or persistent spring snow cover has been associated with Wolverine dens throughout their distribution (Magoun and Copeland 1998; Copeland *et al.* 2010; May *et al.* 2012), but few dens have been described in low elevation, forested habitats. The majority of published information on Wolverine dens is from regions where deep snow was associated with steep, rugged terrain, and large boulders in Norway (May *et al.* 2012), woody debris and boulders in British Columbia (Krebs and Lewis 2000), long complex tunnels (Magoun and Copeland 1998) and drainage features in Alaska (Magoun *et al.* 2017), and fallen trees or boulders in Idaho (Copeland 1996; Magoun and Copeland 1998). A Wolverine denned under large boulders and downed trees in the low-elevation boreal forest of Ontario (n = 1 den; Dawson *et al.* 2010) and females used boulder complexes in mature, mixed-coniferous boreal forests in Sweden (n = 49 dens; Makkonen 2015). Given a lack of steep terrain and large boulders, a shallow snowpack, and relatively early spring snowmelt in the lowland boreal forest of northern Alberta (Webb *et al.* 2016), it was unclear what resident Wolverines were using for denning structures.

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Similar to Wolverines, American Black Bear (*Ursus americanus*) gives birth in winter and need to select den sites that will keep cubs dry, warm, and safe. In the northern boreal forests, most black bear dens are excavated, typically beneath ground level, under the roots of standing or partially blown-down trees, into hillsides, or into riverbanks (Fuller and Keith 1980; Klenner and Kroeker 1990). American Black Bear dens are typically in more upland forest stands, and peatland is avoided (Tietje and Ruff 1980). We hypothesized that in northern boreal landscapes, Wolverine dens located in upland habitat with mature forest cover and deeper snowpack would provide the best protection and insulation available, while more lowland, wet areas would not be used.

Although long-term fur harvests and images captured at camera traps suggest a reproducing population of Wolverines in northern Alberta (Webb *et al.* 2016), very little is known about denning ecology. Documenting den structures, snow conditions near dens, and duration of use, particularly in areas outside of the expected distribution of spring snow cover, could help clarify the relationship between Wolverines and snow and be useful information for timber harvest planning. Currently, Alberta's timber harvest guidelines list Wolverine dens under the "other species/sensitive site" section of the document, suggesting a forested buffer distance of 100 m (Alberta Agriculture and Forestry 2016); yet, there is no description of how to identify a potential Wolverine den. Our objectives were to: (1) document the general forest characteristics and specific structures associated with Wolverine den sites; (2) characterize snow, land cover, and industrial disturbance surrounding Wolverine den sites; and (3) summarize female Wolverine movements during the denning period (February–May).

Methods

The study area, roughly 4600 km^2 in size, is located ~500 km north of Edmonton and 100 km northeast of Red Earth Creek in north-central Alberta (57°N, 114°W; Figure 1). The landscape is typical of Alberta's boreal region (Natural Regions Committee 2006), with a mosaic of aspen (*Populus* spp.)-dominated and aspen/White Spruce (*Picea glauca* (Moench) Voss) mixedwood forests in the uplands and extensive areas of Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) treed fens and bogs in the surrounding wetlands. Approximately 42% of the study area is comprised of wetlands (fens, bogs, swamp, open water, and marsh), which were predominantly peatland forms (fens or bogs; 30% of the study area; AEP 2015). Mean elevation of overlapping townships within the study area is 616.98 m (SD = 89.56, n = 75 townships) and ranged from 500 to 800 m. Summers are short and cool, and winters are cold with snow typically covering the ground from November to mid-April. Mean August temperature in the study area was 13.68 ± 1.86 (SD) °C (mean maximum August temperature = 18.2°C, n = 5 weather stations, 2003–2009; ACIS 2015).

The study area supported low numbers of Moose (*Alces americanus*) and White-tailed Deer (*Odocoileus virginianus*), and had a limited number of American Beaver (*Castor canadensis*); Gray Wolf (*Canis lupus*) occurred in small numbers when compared to other regions of the province. Caribou (*Rangifer tarandus*) are rare, but known to occur in the northern portion of the study area. American Black Bear, Canada Lynx (*Lynx canadensis*), American Marten (*Martes americana*), Fisher (*Pekania pennanti*), Ermine (*Mustela erminea*), Snowshoe Hare (*Lepus americanus*), Red Squirrel (*Tamiasciurus hudsonicus*), Spruce Grouse (*Falcipennis canadensis*), and Ruffed Grouse (*Bonasa umbellus*) were common.

The study area is remote and uninhabited, with little human activity due to limited access and extensive wetlands. The industrial footprint is small and comprised primarily of oil and gas development (e.g., all-season gravel roads, seismic lines from past exploration, and well-sites), with active forest harvesting occurring only in the extreme southern portion of the study area. Many of the seismic lines had experienced considerable regrowth of alder (*Alnus* spp.) and other shrubs. Active wells are visited on a regular basis by oil field staff, while unmaintained wells in the area (some of which were reclaimed and having shrub regrowth) receive little to no winter visitation based on our observations while working there. Gravel road and well-site density (including active and unmaintained wells) was 0.04 km/km^2 and 0.13 wells/km^2, respectively. Large wildfires were the primary disturbance in the area and approximately one-third of the study area had burned in the past 50 years (1961–2016).

We used baited run pole camera traps during winters 2014/2015 (n = 8 run poles), 2015/2016 (n = 7 run poles), and 2016/2017 (n = 14 run poles) to document the presence of individual Wolverines based on unique markings (Magoun *et al.* 2011). During winters 2015/2016 and 2016/2017 (November–March), we live-trapped Wolverines using 10 and 17 log box traps, respectively (Copeland *et al.* 1995). The run poles and live traps were spaced ~5–10 km apart and were baited with beaver carcasses. Traps were outfitted with TT3 trap transmitters (Vectronic Aerospace, Berlin, Germany), which instantly sent an email message via satellite communication when a trap was triggered. On the advice of a wildlife veterinarian,

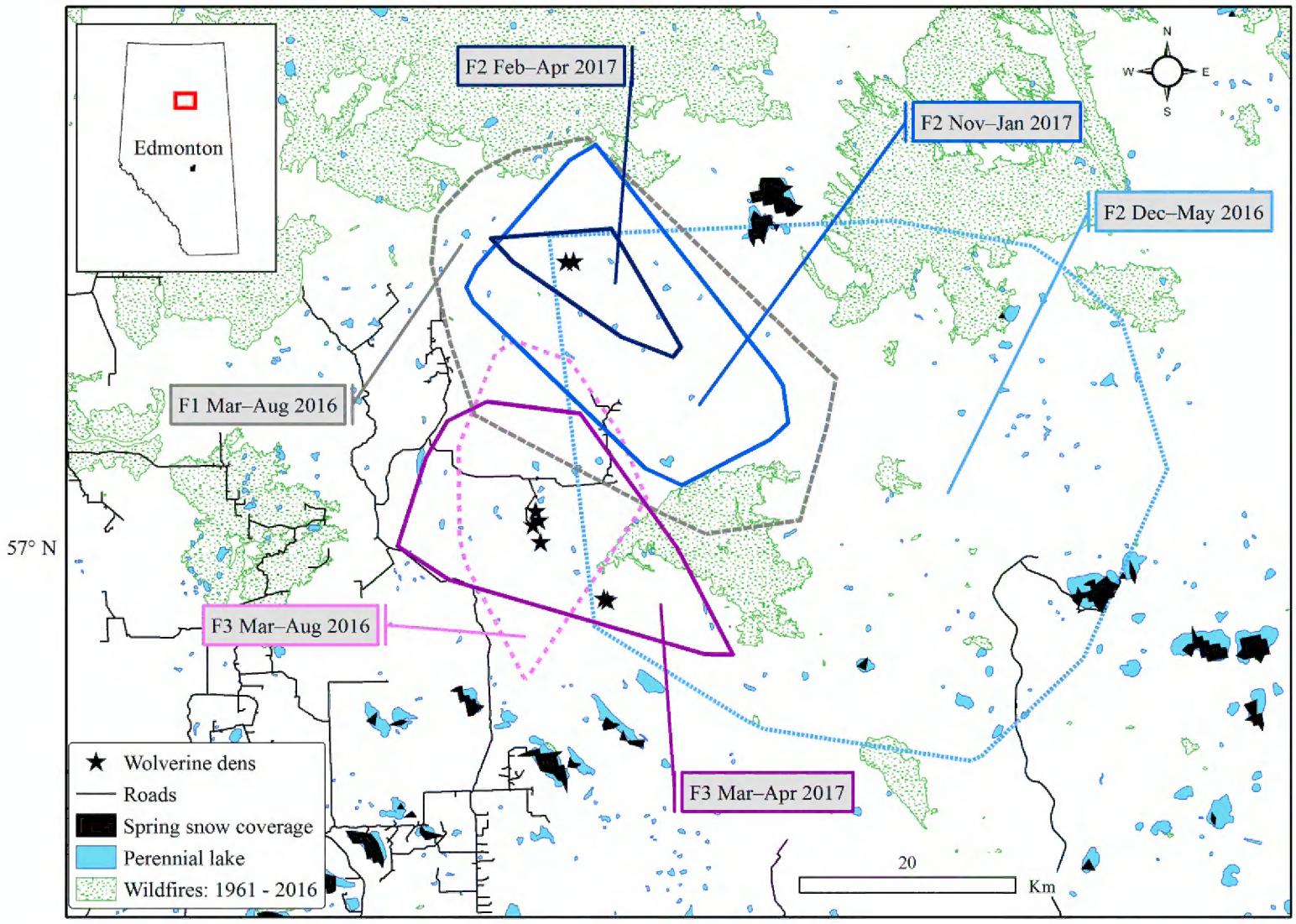

FIGURE 1. Wolverine (*Gulo gulo*) den locations (stars) and 100% minimum convex polygon home ranges for three female Wolverines from 2015–2017 in north-central Alberta, Canada (inset).

Wolverines were immobilized using a jab stick (Dan-Inject, Borkop, Denmark) loaded with ketamine hydrochloride, 100 mg/ml (Ketalean; Bimeda-MTC Animal Health Inc., Cambridge, Ontario) and medetomidine hydrochloride, 1 mg/ml (Cepetor; Modern Veterinary Therapeutics, Miami, Florida, USA) at a dosage of 10.6–11.9 mg/kg and 0.1–0.12 mg/kg, respectively. Wolverines were equipped with Tellus ultralight global positioning system (GPS) collars (Followit, Lindesberg, Sweden) that were programmed to take a location every two hours. Atipamezole hydrochloride 5 mg/ml (Revertor; Modern Veterinary Therapeutics) was hand injected to reverse the effects of the sedative. The animals were returned to the trap on a bed of spruce boughs until fully recovered and then released.

Collars uploaded data to a secure website via satellite communication, but there was typically a 2–3 day time lag until locations became available. We visually inspected GPS collar data to identify potential reproductive den sites. Potential dens had a repeated pattern of collar locations within 100 m of each other and movements to/from a localized area, in addition to associations with long periods of GPS time-outs when we assumed females were underground in the den and satellites were not able to get a fix (February–April). The primary den was the first den we documented and secondary dens were subsequent dens used by female Wolverines (Makkonen 2015). We used the terms primary and secondary dens, similar to Makkonen (2015), because collaring sometimes occurred after kits were born; therefore, we could not be certain that the primary den was actually the natal den.

We used a geographic information system (ArcMap 10.4, Esri, California, USA) for all spatial calculations. We created a 5 km buffer around each den (estimated average female home range during the denning season; Makkonen 2015) and calculated density of gravel roads and well-sites (active and unmaintained). We measured distance of each den site to nearest gravel road and well-site rounded to the nearest whole number. We used multiple sources of data to characterize the study area climate. During winter 2016/2017, we established winter weather stations (n = 12) that were 10–20 km apart to measure local climate variables throughout the study area. Air temperature was recorded every hour using a Kimo KT50 compact temperature logger (Chevry-Cossigny, Seine-et-Marne, France). The temperature logger was not able to record temperatures below −40°C; how-

ever, these were infrequent events. Snow depth was recorded by field staff on a weekly to biweekly basis using a stationary metal metre stick. Study weather stations were established in areas avoiding direct sunlight and unnatural tamping, drifting, or interception of snow. In addition to the winter weather stations we established, we summarized long-term (2005–2017) mean monthly temperature (°C) at the nearest (<20 km) five government-maintained weather stations surrounding the study area (i.e., Trout Mountain/Peerless Lake, Chipewyan Lake, Loon River, Panny River, and Picadelly; ACIS 2015).

We used the spring snow coverage data from Copeland *et al.* (2010), which was estimated across the Wolverine's circumboreal range using MODIS, to classify 500 × 500 m pixels over seven years (2000–2006). For each year, pixels received a one when the raster image was classified continuously as snow without any bare ground during the approximate end of the Wolverine denning period (24 April–15 May); the total number of years with continuous snow cover until mid-May was summed to get a value between one and seven for each pixel (Copeland *et al.* 2010). We created a 5 km buffer around each den site and calculated percent of area with spring snow coverage. We also used snow depth data from the Canadian Meteorological Centre (CMC) which was derived using interpolation models that incorporated actual daily snow measurements from weather stations, meteorological aviation reports, and special aviation reports from the World Meteorological Organization information system (Brasnett 1999; Brown and Brasnett 2010). We summarized long-term (1998–2014) mean monthly snow depths for CMC locations within our study area. We also inferred snow conditions using remote cameras and ground and aerial observations during a field visit in April 2017.

We created a 500 m buffer around each den site to characterize upland land cover (circa 2010; Castilla *et al.* 2014) and wetlands (circa 2015; AEP 2015). Land cover near dens included coniferous forest, broadleaf/deciduous forest, mixed forest, grassland, and shrubland. Wetland classes near dens included swamp, fen, and bog. We also overlapped den sites with the Derived Ecosite Phase, which is a representation of the vegetation, soil, and moisture conditions (wetland and upland; Figure 2) based on Alberta Vegetation Inventory and LiDAR (circa 2017; Alberta Agriculture and Forestry 2017).

We collected additional details related to forest structure and ecological classification at den sites during November and December 2017. Forest structure data were collected at five, 5.64 m radius plots. One plot was established at the den and the additional four plots were 30 m from the den in the four cardinal directions. Plot trees were identified to species and diameter at breast height was measured using a steel diameter tape for all trees >5 m in height. Tree heights were measured with a clinometer and tree ages were determined using an increment borer, typically from the two trees having the largest diameter within each plot. We defined stand age class as young (20–49 years), mature (50–119 years), and old (≥120 years), similar to Stelfox (1995). Each plot was classed to an ecosite phase, which is an Alberta-based field guide that subdivides forest types using site characteristics (moisture and nutrient regime), plant community type, soil type, and forest productivity information (Beckingham and Archibald 1996). Internal den dimensions were strictly based on a visual estimate as we did not want to enlarge the entrance and alter den structures.

Means ± SD are reported for all parameters, unless otherwise indicated.

Results

The nature of the terrain (bogs and extensive wetlands), limited our ability to operate in the field beyond March. The transition from frozen to thawed ground occurred quickly (early April) and access to our remote field camp and the bulk of the study area was impractical. Therefore, we were unable to collect weather station data or monitor dens and litters during the denning months of April and May.

Female Wolverines

We captured four females (F1, F2, F3, and F4) over two winters (2015/2016 and 2016/2017). A year prior to our live captures, we identified F1 from camera images at run poles. F1's home range during the denning season (March–May) was similar (859 km^2, 100% minimum convex polygon [MCP], n = 746 locations) to her overall home range from 21 March to 2 August 2016 (869 km^2, 100% MCP, n = 1046 locations; Figure 1). We had no evidence that she was lactating or denning.

We captured F2 during two winters. F2's home range 19 December 2015 to 15 May 2016 was 2254 km^2 (100% MCP, n = 1642 locations; Figure 1), which was similar to her home range during the denning season that year (February–May; 2219 km^2, 100% MCP, n = 1163 locations). She showed no sign of lactation or denning during this first winter and we suspect that she may have been a young female that ultimately took over the neighbouring F1's territory. We recaptured F2 on 30 November 2016 and again on 21 February 2017, and discovered she was lactating. Based on her subsequent movements and GPS timeouts, we believe she gave birth to her first litter of kits on or shortly after 22 February 2017, ~9 km from where she was captured. Her collar largely timed-out

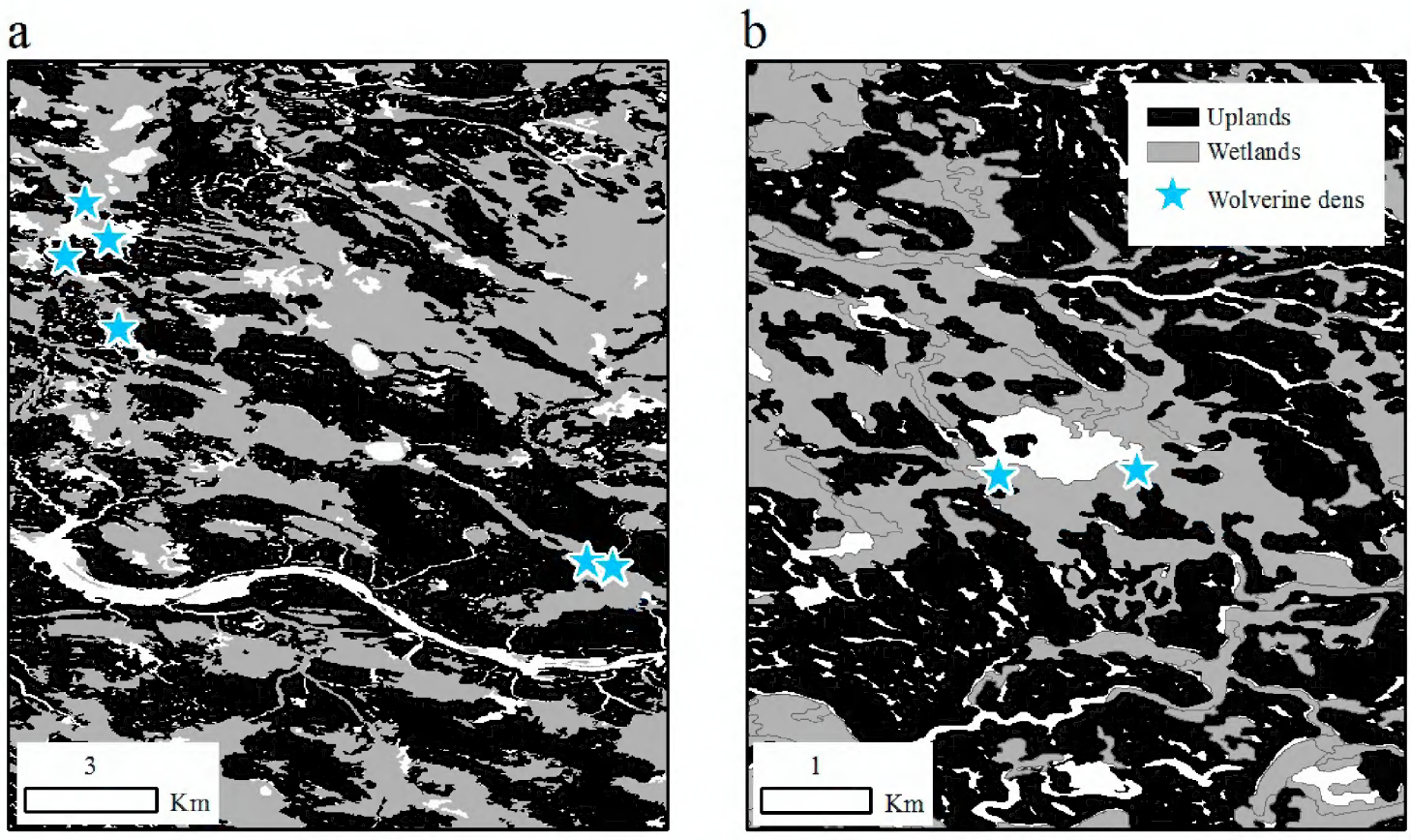

FIGURE 2. Upland and wetland matrix surrounding F3 (a) and F2 (b) den locations during 2016 and 2017 in north-central Alberta—only one den (F3 den 2, 2016) was within the upland category.

over a week-long period starting on 23 February and continued to time-out on a regular basis over the next several weeks. We monitored her movements until 9 April 2017 (premature collar failure) and documented her primary and secondary den (Figure 2b). F2 demonstrated strong fidelity to the primary den during the first four weeks (Table 1). The greatest movement she made was ~12.5 km from her secondary den on 23 March 2017 to a location she had visited earlier in the winter, to feed on remnants of an American Black Bear hide. F2 used her primary den 22 February–13 March and secondary den until at least 26 March; the distance between the two dens was ~700 m. We suspect that F2 had another den (26 March–9 April), but we were not able to locate a third den when we searched a cluster of locations in late April. At a location where F2 had spent time (1–9 April), we did find three mounds of dead spruce limbs that had recently been broken off the lower section (~0.8 m) of spruce trees. The breaking and piling of limbs appeared deliberate and bed-like, similar to the observation reported by a Finnish Wolverine hunter/trapper in Pulliainen (1968). F2's home range from November to January was 484 km^2 (100% MCP, $n = 555$ locations), and 90 km^2 (100% MCP, $n = 309$ locations) while she was denning (February–April; Figure 1). F2's mean daily movements from February to April were <5 km, providing further evidence of raising young in 2017, especially when compared to the previous year when she did not raise young and her daily movements were 8–15 km during the same time period (Table 1).

We captured F3 during two winters. During the first winter, our staff set up trail cameras close to her secondary den and she moved immediately afterwards to a third den (Figure 2a); camera images documented F3 and her three kits leaving the den on the evening of 19 April 2016. Based on this experience, we chose not to visit female den sites during the denning period as we would not be able to determine whether the use of multiple dens was natural or influenced by researchers. We did receive collar location data for F3 after 4 May 2016, which was the last day she occupied den 4. Over the next 27 days, F3 spent six days at one GPS cluster location and three

TABLE 1. Summary of daily movements (number of days, mean ± SD km) made by female Wolverines (*Gulo gulo*) in each month of the denning season during 2016 and 2017 in north-central Alberta.

Female_Year	February		March		April		May	
F1_2016	—	—	11	8.58 ± 6.10	30	11.18 ± 8.80	31	11.19 ± 5.13
F2_2016	29	8.22 ± 7.12	31	10.92 ± 7.26	30	15.19 ± 8.16	15	13.03 ± 4.95
F2_2017	7	2.67 ± 4.22	31	3.62 ± 5.03	8	4.58 ± 3.31	—	—
F3_2016	—	—	9	6.89 ± 6.65	30	10.23 ± 8.50	31	8.48 ± 8.12
F3_2017	—	—	10	9.11 ± 5.64	23	13.83 ± 10.69	—	—

days at two additional locations but these remaining GPS clusters were not visited. F3's home range during the denning season (March–May) was 315 km^2 (100% MCP, n = 500 locations), which was similar to her overall home range 22 March–16 August 2016 (338 km^2, 100% MCP, n = 878 locations; Figure 1). We recaptured F3 on 21 March 2017 and she was lactating; indicating that F3 had litters in two consecutive years. F3 used her primary den until 9 April and then occupied a secondary den 400 m away until at least 23 April (premature collar drop; Figure 2a). Her home range 21 March–27 April 2017 was 406 km^2 (100% MCP, n = 193 locations; Figure 1). Distance between F3's 2016 and 2017 primary dens was ~8 km. Although home range size was similar between years, F3 moved further distances in 2017 compared to 2016, and daily movements were much greater than the denning F2 (Table 1).

We captured F4 twice during March 2017, but she showed no signs of lactation in camera images or while we handled her 2 March and 26 March 2017. Her collar malfunctioned and we were not able to determine home range.

Den descriptions

Because we did not not disturb females while dens were in use and due to the challenges of working in the study area during April and May, most den sites were confirmed the following winter season. We found that using repeated patterns of GPS collar locations in combination with long periods of GPS time-outs to be an effective method of estimating den site locations. In 2016, F3's primary den was 20 m off our estimated GPS location and was confirmed with fresh Wolverine tracks leading in and out of the den. F3's secondary den in the regenerating cutblock was 10 m off our estimated location and was confirmed by very high frequency (VHF) signal and trail camera images. In 2017, F2's primary den was 10 m off our estimated location and was confirmed with packed snow/paths leading into the den. The remaining den locations that were visited the following season were an average of 21 m off the point derived from GPS clusters and time-outs. Alternative den structures in the immediate area of the estimated den locations were limited.

Seven of the eight Wolverine dens (n = 3 primary, n = 5 secondary) were in the hollow created by a partially uplifted root mass (i.e., root ball, root wad; hereafter uplifted root mass) of a leaning or fallen spruce tree. Seven of eight dens were located in mature (50–119 years) or old (>120 years) Black Spruce stands. Two of the seven dens were in mossy formations originating from an uplifted root mass where the trees had decayed, while the other dens were braced by the roots of intact leaning or fallen spruce trees. Root mass dens require little to no excavation by a Wolverine because a natural cavity is created when a thick moss blanket separates from the soil below as the shallow roots of a leaning or fallen tree upheave. Essentially, the lateral roots form the skeleton of the den, which supports a dense mat of soil and moss

FIGURE 3. Wolverine (*Gulo gulo*) F3 2016 primary den was in a partially uplifted root mass of a leaning spruce tree. The den entrance is located along the upper side of the tree trunk in the centre of the den cavity. Photo: Michael Jokinen.

FIGURE 4. An example of a Wolverine (*Gulo gulo*) den underneath a partially uplifted root mass (F3 den 4, 2016) in the lowland boreal forest of north-central Alberta. The den entrance is located at the exposed root; the tree is lying on the ground (upper right) while the lateral roots opposite the entrance have curved, creating a natural cavity. Photo: Michael Jokinen.

creating the den walls (Figures 3 and 4). It is important to note that these root dens are not wind throw trees characterized by roots that have been pulled out of the ground and are left standing on end. Such trees also existed within the study area, but exposed standing roots do not create the mound and associated cavity that the Wolverines used in our study.

Estimated internal den dimensions were slightly variable in size, but den size was ultimately determined by the extent of the root heave (~1 m × 1 m). A soccer ball-sized opening (~30 cm) often created the den entryway and most dens had alternate openings or potential escape routes in the walls. No material was brought into the dens by Wolverine, but spruce cone bracts often lined the floors. Cone seeds have been reported in Wolverine scat (Copeland 1996). However, we observed Red Squirrel caching of intact cones and cone feeding sites, where stripped cones lay beside piles of cone bracts in and around the den location. We did not observe animal remains or Wolverine scat inside or outside the dens. Snowshoe Hare sign was widespread around denning areas when we visited sites in November and December 2017.

One of the eight dens was located under decayed logging debris, which appeared to have been within or adjacent to a landing area used during previous forest harvesting activities. At the time of the observed den use, the overstorey was dominated by dense deciduous regeneration; the landing area and within-block roads were no longer apparent on the ground. We estimated that the cutblock was 27 years old based on tree aging and historical imagery from Google Earth (Google, Mountainview, California, USA), which suggested that the block was harvested in 1987. We could not determine the interior characteristics of this den without destroying the integrity of the structure.

Ecosite classification at den sites

Three primary and three secondary dens were revisited in November and December of 2017 to collect forest structure data. Two of F3's secondary dens from 2016 were not included in this den site forest assessment; however, they were similar in structure (uplifted root mass) and were dominated by old spruce forest based on observations made during a September 2016 visit. The study area is located

within the transition zone of the Boreal Mixedwood and Boreal Highlands ecological areas (Beckingham and Archibald 1996). The Boreal Mixedwood and Highlands are ecologically similar, but the Highlands are slightly cooler (1.7°C cooler in summer) and have higher precipitation in both summer and winter (28 mm higher in summer; winter comparison not available; Beckingham and Archibald 1996).

Based on the ecosite field guide of Beckingham and Archibald (1996), three of five dens (not including the den in the regenerating aspen stand) were an ecosite of Common Labrador Tea (*Rhododendron groenlandicum* (Oeder) Kron & Judd)/horsetail (*Equisetum* spp.) in the Boreal Mixedwood ecological area and two were an ecosite of horsetail and White Spruce in the Boreal Highlands. Of the three Boreal Mixedwood den locations, all sample plots but one (treed poor fen) were identified to a Labrador Tea/horsetail phase. The most common indicator species that we found at these ecosites included Black and White Spruce, alder, Labrador Tea, and horsetail. All but one sample plot (Labrador Tea-hygric Black Spruce-Jack Pine (*Pinus banksiana* Lambert)) at the two dens located in the Boreal Highland ecological area were identified to a horsetail and White Spruce ecosite phase. Indicator species at the two dens in this ecosite were similar to those found at Boreal Mixedwood ecosites. The conifer forest bordering the regenerating deciduous cutblock, in which F3's secondary den was located, appeared to consist primarily of a Labrador Tea/horsetail ecosite class of the Boreal Mixedwood. Table 2 lists the tree species, count and average tree diameter, height, and age measured at sample plots.

Disturbance, land cover, and climate

The elevation of dens ranged from 535 to 687 m above sea level (601.5 ± 52.6 m, $n = 8$; Table 3). F2's dens were at similar elevations to the mean elevation of the surrounding township (681 m). F3 denned in the same township over two consecutive winters (township elevation = 557 m). Dens were typically far from roads and wells (Table 3); however, that could simply reflect available habitat within the study area. Gravel road density within a 5 km buffer of each den was 0–0.18 km/km^2 (0.07 ± 0.08 km/km^2, $n = 8$ dens). Well density (active and unmaintained) within the 5 km buffer of each den was 0.04–0.08 wells/km^2 (0.06 ± 0.02 wells/km^2, $n = 8$ dens).

Conifer forest was the dominant land cover within the 5 km buffer for six of the eight dens (range: 50–100%). One den was 54% deciduous forest, 21% mixed forest, 21% conifer forest, and 3% shrub within this buffer area. The area surrounding the logging debris den had been classified as 65% shrub (primarily regenerating *Populus* spp. within a cutblock), 30% conifer forest, 3% grassland, and 2% deciduous forest; however, the regenerating cutblock had reached heights >10 m by 2016. There was a wide range in the amount of wetland within 500 m of each den (range: 10–74%; 33.7 ± 21.28%, $n = 8$ dens). The wettest den (74% wetland) was classified as 53% swamp, 18% fen, and 3% bog within 500 m (F2's primary den). Six of the eight dens, however, had 10–35% wetland (mostly peatlands) within 500 m. Moreover, based on the Derived Ecosite Phase data, six of eight dens fell within the wetland category. This category is described as hydric/poor dominated by shrubby, treed bog vegetation (Alberta Agriculture and Forestry 2017).

Wolverine dens were 4–7 km to the nearest study weather station. Mean snow depths for each month were 32.4 ± 12.6 cm in December, 37.6 ± 11.1 cm in January, 41.4 ± 14.7 cm in February, and 34.0 ± 17.8 cm in March ($n = 12$ stations; Table 4). Maximum snow depth recorded (December–March) at individual weather stations was 32–51 cm. Hourly temperatures in the study area increased by the latter half of March (16–29 March, daily −3.6°C), as compared to the first half of the month (1–15 March, −16.8°C). Mean monthly temperatures increased slightly with each month, while monthly ranges were highly variable: December −14.4 ± 6.8°C (range −36.0 to 2.9°C),

TABLE 2. Forest stand structure (count, mean ± SD) associated with Wolverine (*Gulo gulo*) dens ($n = 6$) during 2017 in the lowland boreal forest of north-central Alberta.

Den	Tree DBH* (cm)		Tree height (m)		Tree age (yrs)		Stem count†
F3_1_2016	32	49.1 ± 20.4	10	17.6 ± 4.7	10	116.9 ± 44.9	23 Sb, 8 Sw, 1 Lt
F3_2_2016	83	31.3 ± 10.5	10	14.5 ± 3.5	10	26.6 ± 0.7	19 Pb, 18 Aw, 15 Sw
F2_1_2017	113	23.4 ± 12.2	10	13.4 ± 3.1	10	70.5 ± 22.7	87 Sb, 19 Sw, 7 Lt
F2_2_2017	84	30.6 ± 15.9	10	16.0 ± 4.1	10	85.8 ± 28.7	51 Sb, 22 Sw, 10 Lt
F3_1_2017	70	42.8 ± 25.7	10	19.0 ± 6.1	10	121.9 ± 37.5	70 Sb
F3_2_2017	40	57.6 ± 25.5	10	24.2 ± 4.2	10	114.6 ± 18.3	40 Sb

*Diameter at breast height (DBH).

†Trees in plot >5 m tall. Species: Trembling Aspen (Aw; *Populus tremuloides* Michaux), Balsam Poplar (Pb; *Populus balsamifera* L.), Black Spruce (Sb; *Picea mariana* (Miller) Britton, Sterns & Poggenburgh), Tamarack (Lt; *Larix laricina* (Du Roi) K. Koch), and White Spruce (Sw; *Picea glauca* (Moench) Voss).

TABLE 3. General summary of Wolverine (*Gulo gulo*) dens found in the lowland boreal forest during 2016 and 2017 in north-central Alberta.

Den	Date occupied	Elevation (m)	Entrance aspect	Nearest road (km)	Nearest active wellsite (km)
F3_1_2016	mid Feb–9 Apr*	561	S	2.0	2.0
F3_2_2016	10 Apr–19 Apr	590	S	0.4	0.4
F3_3_2016	20 Apr–23 Apr	607	E	1.0	0.9
F3_4_2016	24 Apr–4 May	615	NW	1.0	0.9
F2_1_2017	22 Feb–13 Mar	673	N	12.0	10.4
F2_2_2017	14 Mar–26 Mar	687	SE	12.0	10.3
F2_3_2017	27 Mar–9 Apr†‡	—	—	—	—
F3_1_2017	mid-Feb–9 Apr*	544	W	10.0	10.9
F3_2_2017	10 Apr–23 Apr†	535	S	10.0	11.0

*F3 denning start date is approximate, as she was collared after kits were born in both instances.
†Collar failure or premature collar drop.
‡Unconfirmed den location.

January −14.0 ± 10.2°C (range −40.0 to 10.5°C), February −12.7 ± 10.1°C (range −40.0 to 19.2°C), and March −10.6 ± 10.8°C (range −38.8 to 14.4°C; Table 4). Mean monthly temperatures were similar between long-term data from nearby government stations (2005–2017) and monthly study station temperatures measured during winter 2016/2017 (Table 4).

CMC model grid points were 7–13 km from Wolverine den sites and indicated that snow depths are typically shallow in our study area (December–March, 21.66 ± 1.77 cm, range 19.74–25.03 cm, n = 10 stations; Brown and Brasnett 2010). Snow depths interpolated for points within the study area were slightly higher than mean monthly snow depth trends in the boreal forest of Alberta (February: 25.57 cm, March: 24.24 cm, n = 686 stations; Webb *et al.* 2016).

Spring snow coverage (Copeland *et al.* 2010) was limited (0.38%) and patchy (mean size 1.6 ± 2.68 km^2, n = 11 patches) in our study area. There were no instances of spring snow coverage predicted near Wolverine dens. Mean distance from dens to nearest spring snow coverage was 15.19 ± 2.73 km (n = 8). All patches of the spring snow coverage in the study area corresponded to lakes or large ponds that would be expected to retain at least some ice cover beyond when snow in the forest had melted.

We used trail cameras to document spring snow conditions for F3's primary and secondary dens in 2016. Her primary den was completely snow-covered on 30 March 2016 and 20 days later the snow had all melted. There was no snow cover surrounding the area of F3's secondary den on 19 April 2016. We visited the study area 25–27 April 2017 to retrieve dropped radio collars and observed patchy snow cover across the entire region, from the air (Figure 5) and on the ground. We used an Argo (New Hamburg, Ontario, Canada) to access the area of F2's primary den (2017) as she had not used this den for several weeks and patchy snow cover was encountered at the time. We did not locate F2's secondary den until November 2017 as we were not confident that she was finished using the den during our April visit. We flew over (Figure 5) and hiked within 1 km of F3's 2017 dens while retrieving her dropped radio collar and encountered sparse snow cover throughout the area.

Discussion

Wolverine pregnancy is largely dependent on body

TABLE 4. Mean temperature and snow depths (± SD) recorded at study weather stations (2017), government weather stations (2015–2017), and Canadian Meteorological Centre (CMC) locations (1998–2014) during December–May in north-central Alberta.

Weather station	December	January	February	March	April	May
Study stations						
Temperature (°C) n = 12	−14.4 ± 6.8	−14.0 ± 10.2	−12.7 ± 10.1	−10.6 ± 10.8	—	—
Snow depth (cm) n = 12	32.4 ± 12.6	37.6 ± 11.1	41.4 ± 14.7	34.0 ± 17.8	—	—
Government stations and CMC estimates						
Temperature (°C) n = 5	−15.8 ± 0.7	−18.1 ± 0.8	−13.9 ± 0.8	−7.5 ± 0.6	2.5 ± 0.2	8.7 ± 0.2
Snow depth (cm) n = 10	14.7 ± 1.2	21.3 ± 1.5	26.5 ± 2.1	24.2 ± 2.6	5.6 ± 1.2	0.2 ± 0.1

FIGURE 5. Snow cover near Wolverine (*Gulo gulo*) F3 primary den on 27 April 2017 in north-central Alberta. Photo: Michael Jokinen.

condition and winter food availability (Persson 2005), because of delayed implantation (Banci 1994). It has been hypothesized that dens that provide females and their offspring with secure shelter from disturbance (e.g., predation, weather, people), thermal insulation (Magoun and Copeland 1998), and access to adequate food resources (Inman *et al.* 2012) may be more likely to produce successful litters. Nearly all documented Wolverine dens in the world have been associated with deep snow (Magoun and Copeland 1998) and/or persistent spring snow cover (Copeland *et al.* 2010); however, Wolverines have not been studied equally across their range (Banci 1994), particularly in North America. We recognize that our sample size of denning females was small and that reproductive success was not measured for those females; however, our study detected a Wolverine denning strategy that is largely undescribed. We documented Wolverine dens in low elevation forests lacking boulders and deep or persistent spring snow, where a core, resident population has supported Wolverine harvests for over 30 years (Webb *et al.* 2016). Our results provide further evidence that Wolverines are adapted to exploiting cold, low productivity environments, but females appear to be selecting denning habitat that differs from what we hypothesized and what has been reported elsewhere.

In addition to shallow snow cover, our study area had other unique differences from other Wolverine studies. Ungulates can be important in the diet of female Wolverines (Banci 1994; Inman *et al.* 2012), yet ungulates were in low abundance in our study area and in much of the boreal forest, where smaller prey including American Beaver, Snowshoe Hare, and grouse are more common. Female Wolverine in northern British Columbia were positively associated with rugged terrain in alpine environments, where Hoary Marmot (*Marmota caligata*) and Columbian Ground Squirrels (*Urocitellus columbianus*) were common (Krebs *et al.* 2007). Although the Omineca region of British Columbia is at similar latitude, our study area does not support this prey or terrain selection. Not unlike the difference between northern mountain and boreal ecotypes of Woodland Caribou (Wood and Terry 1999; ASRD & ACA 2010), Wolverines in our study area must meet their needs in a very different environment. Although we lacked data on winter food availability, we documented one female that

denned in two consecutive years, with three kits confirmed to be alive at ~4–6 weeks of age in the first year. Snowshoe Hare and Canada Lynx sign was common during our study. Based on Canada Lynx harvests, Snowshoe Hare cycle peaks in Alberta have occurred around 1980, 1990, 2000, and 2010 (Webb *et al.* 2013). Snowshoe Hare numbers were increasing during our study (N. Kimmy pers. comm. 30 January 2019). The habitat within our study area was highly mosaic, likely a result of frequent fires and abundant wetlands. Female Wolverines may rely on hunting small prey, such as Snowshoe Hare (Banci 1994; Scrafford and Boyce 2015), and this varied landscape may provide hares the forage, concealment, and thermal cover to persist in relatively good numbers throughout the various habitat types (Hodges 2000; Gigliotti *et al.* 2018). Krebs *et al.* (2018) state that the Snowshoe Hare is one of the few prey species available to predators during the winter in the boreal forest. All avian and mammalian predators in the boreal forest eat Snowshoe Hare (Krebs *et al.* 2018). Wolverine and Canada Lynx harvest data have shown that a pattern may exist between Wolverine harvest and the Snowshoe Hare cycle (Webb *et al.* 2013; Boonstra *et al.* 2018). By denning within mature conifer, female Wolverines in the boreal forest may have access to a prey source in close proximity.

Inman *et al.* (2012) suggest there may be a connection between food storage, persistent spring snow cover, and Wolverine denning requirements. If deep snow may provide an opportunity for food caching in other settings, it begs the question: How are Wolverines meeting this need in a landscape where snow is far less abundant? We do not have the data required to answer this question, but local knowledge may have provided a hypothesis worth testing with future studies. On three independent occasions, trappers in our study area observed a Wolverine having depredated a harvested Canada Lynx from a trap, bringing it into an adjacent peatland area, and caching it. In each case, the trapper reported seeing that the Wolverine had dug through the snow and down into the organic peat layer, then buried the carcass up to 45 cm below the surface with a mixture of snow, moss, and other vegetation. In one case, the trapper reported that the Wolverine had urinated on top of the location before leaving; another reported finding it very challenging to dig into the cache as the infill had frozen solid. Scrafford and Boyce (2015) also documented Wolverines caching in bogs in northern Alberta. We observed instances where it appeared that a wolverine had returned to a peatland cache and excavated and fed on food remnants (M.E.J. unpubl. data). Burying foods into bogs may help preserve excess food for later use (Verhoeven and Liefveld 1997; Moldowan and Kitching 2016) or hinder competitors from locating it. Future research into boreal Wolverine ecology should seek to test this hypothesis.

Wolverine dens have been documented under wind-drifted snow, large boulders, and trees in areas with deep snow (Magoun and Copeland 1998; Krebs and Lewis 2000; Copeland *et al.* 2010; May *et al.* 2012; Makkonen 2015; Magoun *et al.* 2017), but these features are lacking in the boreal forests of northern Alberta. Instead, most dens in our study ($n = 7$) were under partially uplifted root masses of leaning or fallen trees in older spruce forests, while one den was under decayed logging debris in an ~30 year old regenerating deciduous forest. We realize that our sample size of two denning females and their choice of denning structure could be a result of individual preference. However, Scrafford and Boyce (2015) also found Wolverines denning in an uplifted root mass and timber slash pile near Rainbow Lake in northwestern Alberta. Approximately 42% of our study area is comprised of various wetland forms, including a majority made up by peatlands, with a mean elevation of 600 m. Makkonen (2015) notes that no dens were found in peat bogs, despite their abundance on the boreal landscape in Sweden, but Wolverines had access to and used large boulders at higher elevations for denning. Pulliainen (1968) found that half of the Wolverine dens in the boreal forest of Finland were associated with standing or fallen spruce trees; however, the dens and tunnels were established under the length of a fallen tree and were always under deep snow cover (>1 m). In contrast, maximum snow depth in our study rarely exceeded half a metre and was meaningfully absent for the final third of the denning season.

American Black Bears use a variety of den structures across their range, but adequate thermal cover is critical for successful reproduction in northern climates. The most common black bear den was under the roots or stumps of standing or partially blown down trees in the boreal forest of Ontario (Kolenosky and Strathearn 1987), Manitoba (Klenner 1982), and Alberta (Tietje and Ruff 1980), and the den chamber was similar in size to what we measured inside Wolverine dens (~1 m^3). Contrary to black bear dens, however, the Wolverine dens we investigated were not deliberately lined with other materials (e.g., grass, moss, leaves, twigs; Klenner 1982). Instead, most of the Wolverine dens had cone bracts inside that had been discarded by feeding Red Squirrels. Squirrel middens have also been associated with marten den sites (Ruggiero *et al.* 1998) and Western Toad (*Anaxyrus boreas)* hibernation sites (Browne and Paszkowski 2010), where it has been suggested that they may provide some thermal benefit. Marten

will utilize root masses of fallen trees for winter rest sites (Gilbert *et al.* 1997) and den sites can occur underground (Bull and Heater 2000). Browne and Paszkowski (2010) note that Western Toad hibernation sites in north-central Alberta were also located within peat hummocks and decayed root channels.

Mosses are the prevalent ground cover in the wetland environments of the boreal forest. Instead of deep snow (>1 m) providing thermal protection (Magoun and Copeland 1998), it is possible that the thick moss layer insulates Wolverine dens from cold temperatures and excess moisture. Snow accumulation in our study area averages only 30–40 cm, but when combined with the thick, mossy root layer, these den structures may provide adequate thermal insulation. Moss was traditionally used by Laplanders and other circumpolar people for bedding and insulation in both dwellings and clothing (Kimmerer 2003). Various species of moss have been shown to have thermal properties that insulate and limit the fluctuation of soil temperature and moisture (Soudzilovskaia *et al.* 2013). Marchand (2014) suggests that under 40–50 cm of snow, air temperature fluctuations have little influence on subnivean conditions. We suspect that typical late winter snow depth in our study area, in combination with the layer of moss, may also approximate those conditions.

The ecosites in which our dens were located are naturally wet and are rated as having high excess moisture (Beckingham and Archibald 1996). Even though these ecosites have elevated water tables near the ground surface, the den cavities are shallow and not far below the mossy forest floor. Because snow cover is relatively light and the den floor close to ground level, the probability of the den flooding during spring melt would be low.

Wind-throw hazard (i.e., potential for trees to become partially or completely uprooted) is rated as medium-high/high for the ecosites where dens were found in our study area (Beckingham and Archibald 1996). The potential for ready-to-move-in den structures in this forest type is therefore greater. The lateral roots and soil lining create a barrier, although the walls are relatively thin (~15–30 cm) and appear fragile even when snow-covered. The root mass walls provide limited protective shielding from potential danger, so females may be more susceptible to disturbance. However, this did not seem to result in them moving denning sites more frequently, as other studies documented similar number of dens per female as we did (Magoun and Copeland 1998). The proximity of a den structure to potential human disturbance is likely important (Banci 1994). Our study area was remote and most dens were located far from roads and trails, where encounters with people would be rare. In addition to potential direct disturbance at the den, Scrafford *et al.* (2018) suggested that roads may negatively influence Wolverines by altering both habitat use and movement rates through habitat near roads. However, the density of roads near den sites in our study was an order of magnitude less than that of Wolverine home ranges in their study, suggesting that these females may be less impacted by roads. In addition, ungulates were not abundant in our study area, so wolf numbers were not high. This may lessen the need to have a secure den structure as would be provided by a snow cave or large boulders.

Forest companies seeking to provide long term Wolverine denning habitat within low elevation boreal forests have been operating with a paucity of information, trying to determine how to apply what is known about dens from a mountain environment to one largely devoid of boulders and a deep, persistent snow pack. Although our observations are limited, these females, and those of the Scrafford and Boyce (2015) study, provide a glimpse into the unique denning ecology of boreal Wolverines. Until more detailed information can be obtained, forest companies should retain mature representative samples of high-wind-throw-risk ecosites within their planning area. In some cases, forest harvesting may have the potential to create future suitable denning habitat when structure is left behind (e.g., brush piles, log landings). Although the availability of partially wind thrown trees may not be limiting on the boreal landscape, their suitability for den sites may be influenced by the degree of disturbance in the surrounding area.

In the absence of deep snowpack, Wolverines in our study area have found a way to persist in the lowland boreal forest. Our small sample size limits our ability to draw robust conclusions. As such, our observations and speculation about potential ecological processes should be viewed as the basis for hypotheses that can be tested with further study. In a landscape lacking deep snowpack and large boulders, we speculate that Wolverines are able to meet their needs through locally available features such as the cavity created by a partially uplifted root mass, the thermal properties of thick moss, and the caching opportunities provided by deep peat accumulations. Wolverines are resourceful and may be more flexible in their denning requirements than documented by studies in other landscapes.

Author Contributions

Writing — Original Draft: M.J., S.W., and R.A.; Writing — Review & Editing: M.J., S.W., and R.A.; Conceptualization: M.J., S.W., D.M., and R.A.; Investigation: M.J., S.W., and R.A.; Methodology: M.J.,

S.W., and R.A.; Formal Analysis: M.J., S.W., and R.A.; Funding Acquisition: R.A., D.M., and S.W.

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Note

Wolf (*Canis* sp.) attacks life-like deer decoy: insight into how wolves hunt deer?

Thomas D. Gable[1,*] and Daniel P. Gable[2]

[1]University of Minnesota, 2003 Upper Bufford Circle, St. Paul, Minnesota 55108 USA
[2]3176 E Siebert Road, Midland, Michigan 48642 USA
*Corresponding author: thomasd.gable@gmail.com

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Abstract

We know of no documented observations of wolves (*Canis* sp.) detecting and then attacking a White-tailed Deer (*Odocoileus virginianus*) during spring, summer, or fall. We describe an observation of a wolf attacking a life-like, two-dimensional deer decoy in November 2017 near Killarney Provincial Park, Ontario, Canada. The wolf appeared to locate the decoy by sight rather than sound or scent, suggesting that the profile of a deer is sufficient to trigger an attack by a wolf.

Key words: Wolf; *Canis*; carnivore; hunting behaviour; predation; predator-prey; White-tailed Deer; *Odocoileus virginianus*; Killarney Provincial Park

White-tailed Deer (*Odocoileus virginianus*) are the primary prey of wolves (*Canis* sp.) throughout much of the southern boreal ecosystem in North America (Potvin *et al.* 1988; Benson *et al.* 2017; Gable *et al.* 2018). How and where wolves hunt and kill deer during winter is well understood because of the ease of observing wolf-hunting behaviour and locating kill sites from the air (Mech and Frenzel 1971; Fuller 1989; Mech *et al.* 2015). However, equivalent information for the snow-free months is rare, as wolves and deer primarily co-occur in densely forested areas (Demma *et al.* 2007). For example, there are no estimates of wolf kill rates of White-tailed Deer (adults or fawns) during spring to fall, and little information exists about where and how wolves successfully hunt and kill deer during this period (Demma *et al.* 2007; Mech *et al.* 2015). In a comprehensive review of wolf–deer interactions, Mech *et al.* (2015) provided descriptions of eight such interactions during the snow-free season. However, all of these observations occurred after the wolf or wolves had already detected and attempted to chase deer. To our knowledge, there are no observations that demonstrate how wolves find deer during spring to fall. Herein, we document a wolf (*Canis* sp. according to Rutledge *et al.* 2016) attacking a life-like deer decoy that provides rare insight into how wolves locate and detect deer during this period.

During the first week of November, D.P.G. was hunting White-tailed Deer on McGregor Island (46° 04′49″N, 81°35′18″W), about 2 km west of Killarney Provincial Park, Ontario, Canada. Before hunting, D.P.G. set-up a life-like, two-dimensional decoy of a squatting doe ("Estrous Betty", Montana Decoys, Hummelstown, Pennsylvania, USA). The decoy consisted of a life-size photograph of a deer with an internal wire frame, ~1.3 cm thick, for support (Figure 1). The decoy was oriented in an east–west direction so that profile views of the decoy could be seen from the north or south (Figure 2). D.P.G. also left doe urine (details on manufacturer not available) on a branch 1.5 m off the ground 1 m north of the decoy.

At about 1515, after setting up the decoy and dispensing the doe urine, D.P.G. situated himself in a tree stand on a rocky point 23 m west of the decoy. The stand faced east and overlooked a 100-m wide valley dominated by mature Sugar Maple (*Acer saccharum* Marshall) forest between two steep rock ridges (north and south of the stand; Figure 2). On both sides of the valley at the base of the ridges were prominent deer trails running east to west. Immediately to the west of the tree stand was a dense Balsam Fir (*Abies balsamea* (L.) Miller) lowland. About 50 m north of the northern ridge was a 0.5–1.0 km wide channel of

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FIGURE 1. Life-like decoy of a White-tailed Deer (*Odocoileus virginianus*) that was attacked by a wolf (*Canis* sp.) 2 km west of Killarney Provincial Park, Ontario, Canada, during the first week of November 2017. Photo: Daniel Gable.

water; this channel surrounds McGregor Island. The maple forest that the stand overlooked had minimal understorey for about 150 m before transitioning to marshy lowland, which abutted a small shallow cove that was connected to the main water channel. D.P.G. accessed the stand by parking his boat at the northwestern opening of this cove (~300 m east by northeast of the stand). There was no snow cover during this period.

The sky was overcast with moderate (8–16 km/h) winds blowing from the west/southwest. At 1600, D.P.G. noticed a wolf about 150 m east by southeast of the stand trotting along the deer trail on the southern edge of the valley (Figure 2). Given the position of the decoy and the structure and arrangement of the trees, the wolf would have been unable to see the decoy when D.P.G. first spotted the wolf. We later verified this by walking to the wolf's location. The wolf continued at the same pace, moving east to west, until it was about 70 m southeast of the decoy (Figure 2). Without stopping, the wolf turned abruptly and started travelling directly toward the decoy. As the wolf approached, it appeared to be intently focussed on the decoy; however, it maintained a trotting pace for another 30 m. When about 40 m from the decoy, the wolf suddenly sprinted toward the decoy and, when only a few metres away, lunged at it, latching onto its neck, leaving punctures in the fabric of the decoy. The force of the contact ripped the decoy from the ground and caused the wolf and decoy to tumble for about 10 m (total time 2–3 s). After the wolf had stopped its fall, it promptly stood up and jumped back about 10 m. It stood looking at the decoy for a few seconds with both ears and tail lowered. Within a few more seconds, the wolf ran quickly over the steep ridge to the south and disappeared from view.

We know of no other observation of a wolf travelling, detecting, and then attacking a deer or deer facsimile during the snow-free season. Although the decoy was not an actual deer, it looked exactly like a deer (Figure 1) and behaved (stood still staring at the wolf) as deer do when approached by predators (DeYoung and Miller 2011; Mech *et al.* 2015). Given this and the observed changes in the wolf's behaviour after it appeared to detect the deer, we believe that the wolf was convinced the decoy was a deer. As a result, we assert that the wolf's behaviour on detecting and approaching the decoy provides insight into how this

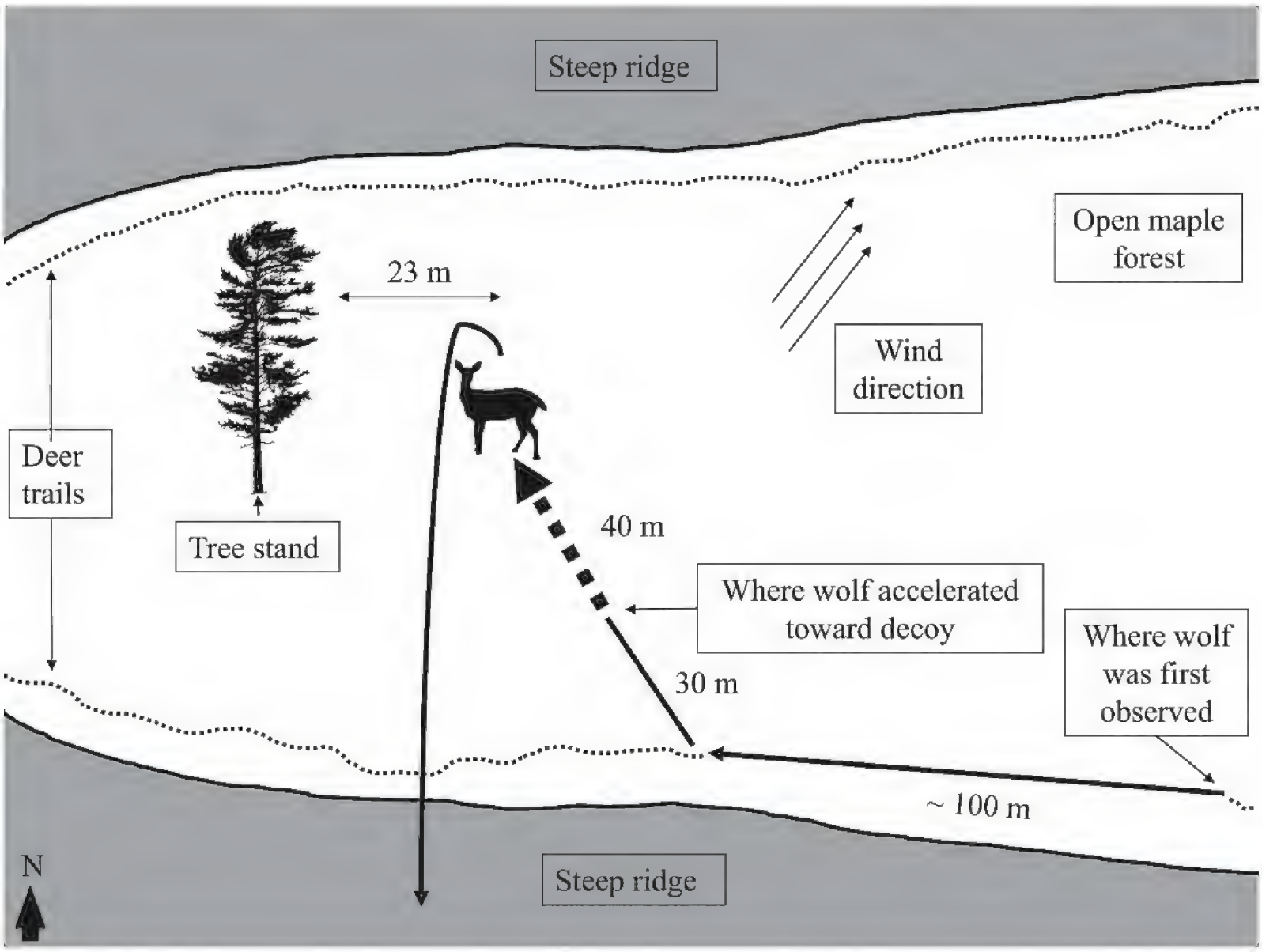

FIGURE 2. Route taken by a wolf (*Canis* sp.) that detected and then attacked a life-like decoy of a White-tailed Deer (*Odocoileus virginianus*) near Killarney Provincial Park, Ontario, Canada, in early November 2017.

wolf, and likely other wolves, may locate deer.

The wind direction and consistent wind flow would have made the doe urine difficult, and likely impossible (Conover 2007), for the wolf to detect during its approach, which strongly suggests that the wolf located the decoy visually. Wolves are thought to be adept at visually detecting slight movements, which likely helps in locating prey (Harrington and Asa 2003), but our observation suggests that wolves are capable of detecting motionless prey from considerable distances. We estimate that the wolf detected the decoy about 70 m away, although detection was likely aided by the minimal understorey and daylight conditions.

Although wolves likely rely on scent to locate deer when hunting (Mech *et al.* 2015), it appears they can also use visual detection, even if not associated with odour, sound, or any other cues. Dense vegetation throughout most of wolf–deer range likely limits visual detection of deer during the summer. However, events that reduce forest or understorey cover (e.g., forest fires, clear-cuts) could enhance the ability of wolves to detect deer and increase encounter rates between wolves and deer (Whittington *et al.* 2011) and possibly wolf kill rates (Sand *et al.* 2005; Vander Vennen *et al.* 2016).

Mech *et al.* (2015: 26) noted that "when wolves detect deer, they usually proceed slowly and deliberately, ever on the alert". However, this wolf approached relatively rapidly after detecting the decoy, closing a ~70 m distance in a matter of seconds. Once 30 m away from the decoy, the wolf apparently decided that the deer (i.e., the decoy) was indeed vulnerable, possibly because it did not move, and sprinted toward it. Wolves generally assess the vulnerability of deer by approaching, chasing, and testing them. Most deer are not vulnerable to predation because they are in sufficiently good physical condition to easily out-run and evade wolves; therefore, most hunting attempts are short lived as wolves realize their efforts are futile (Mech *et al.* 2015).

Our observation provides the only information we are aware of about how at least one wolf approached and attacked what it thought was an adult White-tailed Deer during the snow-free season. Thus, whether the observation is the exception or represents normal behaviour is unknown. Still, it does provide new insight into the predatory behaviour of wolves.

The lack of information on wolf predation of deer—both fawns and adults—during the snow-free season is surprising given the amount of research on wolves, deer, and their interactions. Because of this, we recommend intensive research on wolf–deer interactions during summer as has been done recently with caribou (*Rangifer tarandus;* e.g., Whittington *et al.* 2011; Latham *et al.* 2013; Mumma *et al.* 2017). Indeed, as the range of White-tailed Deer continues to expand northward (Dawe and Boutin 2016), thereby increasing the area that wolves and deer co-occur, such information will only become more valuable and relevant for the conservation and management of both species (Latham *et al.* 2011).

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Birds of Mansel Island, northern Hudson Bay

Anthony J. Gaston

Science and Technology Branch, Environment and Climate Change Canada, Carleton University, Ottawa, Ontario K1A 0H3 Canada; email: tonygastonconsult@gmail.com

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Abstract

A recent review of bird distributions in Nunavut demonstrated that Mansel Island, in northeastern Hudson Bay, is one of the least known areas in the territory. Here, current information on the birds of Mansel Island is summarized. A list published in 1932 included 24 species. Subsequent visits by ornithologists since 1980 have added a further 17 species to the island's avifauna. The list includes 17 species for which breeding has been confirmed and 10 for which breeding is considered probable. The island seems to support particularly large populations of King Eiders (*Somateria spectabilis*) and Tundra Swans (*Cygnus columbianus*) and the most southerly breeding population of Sabine's Gull (*Xema sabini*) and Red Knot (*Calidiris canuta*; probably).

Key words: Mansel Island; Hudson Bay; birds; breeding

Introduction

At 3180 km^2, Mansel Island, Qikiqtaaluk Region, Nunavut, is the 28th largest island in Canada. It is one of three large islands in northern Hudson Bay, the others being Southampton and Coats Islands. Although the birds of Coats and Southampton Islands have been documented (Sutton 1932a; Gaston and Ouellet 1997), those of Mansel Island are comparatively poorly known. Only one publication provides information on the avifauna of the island: a list prepared by G.M. Sutton (1932b) based on specimens provided to him by A.T. Swaffield, the Hudson Bay manager who established the trading post at Swaffield Harbour, near the northern tip of the island, in 1929.

At its nearest point, Mansel Island is 56 km from the mainland of Quebec (Figure 1). The topography is mostly low elevation (maximum 138 m), without any prominent hills or gullies except for a shallow central valley running east–west across the island. Underlying bedrock throughout is Silurian limestone, which is covered, over large parts of the island, by raised beach deposits of Holocene age. There are extensive wetlands throughout, especially in the southwest portion of the island. Sutton (1932b: 41) commented: "an exceedingly flat, dull-gray piece of land". Dry areas support low-growing shrubs, including willow (*Salix* spp.), cranberry (*Vaccinium* spp.), and Four-angled Mountain Heather (*Cassiope tetragona* (L.) D. Don), as well as the tussock forbs, Entire-leaved Mountain Avens (*Dryas integrifolia* Vahl) and Purple Mountain Saxifrage (*Saxifraga oppositifolia* L.). Marshes support extensive sedge (*Carex* spp.) meadows.

The Hudson Bay post on the island closed in 1945, and there has been no permanent habitation on the island since then, although people from the nearby Inuit community of Ivujivik, Nunavik, sometimes visit in summer to hunt Caribou (*Rangifer tarandus*) and Polar Bear (*Ursus maritimus*; Gaston *et al.* 1985).

Sutton's list comprised 24 species, but only 17 of them were collected in summer and, hence, potential breeders, and no evidence of breeding was included (Sutton 1932b). Species were collected at various dates between September 1929 and June 1930. Sutton commented on their likely breeding status, but there was no definite evidence available to support his suggestions. Subsequent ground surveys, all of only one or two days' duration, have added another 17 species to the island's list, and breeding has been confirmed for some. Although this information is based on very brief visits, it is assembled here to give an up-to-date summary of what little is known about the avifauna of Mansel Island.

Methods

Subsequent to Swaffield's collection, three ground surveys have been carried out by ornithologists. In July 1984, R. Decker visited the island for one day by helicopter, landing at several sites. Information

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FIGURE 1. a. Location of Mansel Island in Hudson Bay. b. Localities visited in 1992 and 2016. Source: Mansel Island, Nunavut, 61°59′23.31″N, 79°56′12.54″W. Google Earth Pro 7.3.2.5776. Imagery date: 13 December 2015. Data provider: Landsat/Copernicus 2018. Accessed: 30 July 2018.

from his survey was incorporated into the Land Use Information Series map of Mansel Island (Environment Canada 1970), which includes a list of "avian species which occur or are thought likely to occur within this map-area", but I have only included species definitely sighted on the island during the survey. On 8 and 9 August 1992, A.J.G., V. Johnston, and I. Storm landed from the *M.V. Teregluk* near the easternmost point of the island and spent 10 h ashore surveying an area of lakes, ponds, and marshes adjacent to a shallow bay (Figure 1).

On 20 and 21 June 2016, Y. Aubry, M. Robert, F. Shaffer, and C. Marcotte carried out systematic surveys of breeding birds in two areas (Figure 1), using the protocol of the Program for International and Regional Shorebird Monitoring (PRISM; Bart and Johnston 2012). In addition to total bird counts, species presence or absence was recorded by 1-ha squares. They also touched down at several other sites to make additional observations.

In addition, on 12 July 1984, an aerial survey (Cessna 337) was carried out by R. Decker along the entire coastline and over selected parts of the interior. I did not have access to the original data, but some information from this survey was incorporated into a general survey of larger birds in Foxe Basin and northern Hudson Bay (Gaston *et al.* 1986).

Results and Discussion

Combining the species listed by Sutton (1932b) with subsequent surveys yields 41 species reported from Mansel Island to date, of which definite evidence of breeding, in the form of nests or flightless young, has been obtained for 17 species. A further 10 species were considered by at least one survey to be "probably breeding" (Table 1). Major concentrations of Arctic Terns (*Sterna paradisaea*) and Common Eiders (*Somateria mollissima*) were noted on the aerial surveys of 1984, with an estimated 1000 pairs of Common Eiders on Awrey Island and several colonies of 50–75 pairs of Arctic Terns on the east and southwest coasts (Gaston *et al.* 1986).

Because of the timing of surveys, breeding could be confirmed for fewer than half of the species recorded during the breeding season. The 1992 survey

Table 1. Bird observations and breeding status* at Mansel Island based on four data sets. At-sea records are included where the birds might have been visible from the island.

Species	Sutton 1932b (season)	Decker 1984 (status)	Sightings 1992		PRISM 2016			Surveys recorded	Combined status†
			No. seen	Status	No. squares present	No. seen	Status		
Snow Goose (*Anser caerulescens*)	Fall		250	?	2	3	PR	2	PR
Cackling Goose (*Branta hutchinsoni*)	Summer	B	2	PR	2	3	B	4	B
Canada Goose (*Branta canadensis*)			100	PO	11	27	B	2	B
Brant (*Branta bernicla*)	Summer	B						2	B
Tundra Swan (*Cygnus columbianus*)	Summer	B	2	PR	3	7	B	4	B
Northern Pintail (*Anas penelope*)		B			7	12	PR	2	B
Red-breasted Merganser (*Mergus serrator*)		PR						1	PR
Common Eider (*Somateria mollissima*)	Summer	B	5	PO				2	B
King Eider (*Somateria spectabilis*)	Summer	PR	47	B	10	25	PR	4	B
Long-tailed Duck (*Clangula hyemalis*)	Summer	PR	20	PR	6	10	PR	4	PR
Northern Fulmar (*Fulmarus glacialis*)			2	at sea				1	
Willow Ptarmigan (*Lagopus lagopus*)					5	9	PR	1	PR
Red-throated Loon (*Gavia stellata*)	Summer	B	4	PR	3	7	PR	4	B
Pacific Loon (*Gavia pacifica*)		B	15	B	3	4	PR	3	B
Common Loon (*Gavia immer*)		PR						1	PR
Black-bellied Plover (*Pluvialis squatarola*)	Summer		5	PR	5	8	PR	3	PR
American Golden-plover (*Pluvialis dominica*)	Summer		12	PR	5	12	PR	3	PR
Semipalmated Plover (*Charadrius semipalmatus*)					1	1	PO	1	PO
Whimbrel (*Numenius phaeopus*)	Fall							1	
Red Knot (*Calidris canuta*)	Summer							1	PR‡
Semipalmated Sandpiper (*Calidris pusilla*)			20	PR	4	12	B	2	B
Purple Sandpiper (*Calidris maritima*)	Summer				1	1	PO	2	
White-rumped Sandpiper (*Calidris fuscicollis*)	Summer							1	
Dunlin (*Calidris alpina*)			6	PO	5	8	B	2	B
Ruddy Turnstone (*Arenaria interpres*)	Summer							1	B§
Red-necked Phalarope (*Phalaropus lobatus*)					2	3	PR	1	PR
Red Phalarope (*Phalaropus fulicarius*)	Summer		4	PO	1	2	PO	3	PO
Sabine's Gull (*Xema sabini*)	Summer	B	10	PR	2	4	PR	4	B
Ivory Gull (*Pagophila eburnea*)	Winter							1	
Glaucous Gull (*Larus hyperboreus*)		B						1	B
Herring Gull (*Larus smithsonianus*)	Fall	B	30	B	9	15	PR	4	B
Arctic Tern (*Sterna paradisaea*)		B	50	PR	5	5	PR	3	B
Parasitic Jaeger (*Stercorarius parasiticus*)	Fall		2	PR	3	5	PR	3	PR
Long-tailed Jaeger (*Stercorarius longicaudus*)					1	1	PO	1	PO
Thick-billed Murre (*Uria lomvia*)	Fall		4	at sea				1	

TABLE 1. *Continued.*

Species	Sutton 1932b (season)	Decker 1984 (status)	Sightings 1992		PRISM 2016			Surveys recorded	Combined status†
			No. seen	Status	No. squares present	No. seen	Status		
Black Guillemot (*Cepphus grylle*)	Fall	B						2	B
Horned Lark (*Eremophila alpestris*)			2	B	4	8	PO	2	B
Snowy Owl (*Nyctea scandiaca*)	Summer							1	
Barn Swallow (*Hirundo rustica*)	Summer							1	
Lapland Longspur (*Calcarius lapponicus*)			5	PR	4	12	PR	2	PR
Snow Bunting (*Plectrophenax nivalis*)					1	1	PO	1	PO
Total (breeding)	24	17 (13)	597	(15)	26	205	(20)		B (17), PR (10)

*B = definite evidence of breeding, PR = probable breeding, PO = possible breeding.
†Combined breeding evidence from all surveys to give likeliest status.
‡A satellite-tracked Red Knot was recorded in summer on Mansel Island by Lathrop *et al.* (2018).
§A geolocator-tracked Ruddy Turnstone spent the summers of 2014 and 2015 on Mansel Island and showed evidence of incubation in 2015 (R. Porter pers. comm. August 2018).

was conducted after most shorebirds would have completed breeding, and breeding could not be confirmed in that season for any shorebird species. Those species for which breeding could be confirmed were those that have longer breeding periods. Conversely, surveys in 2016 found the island partly covered in snow, which presumably delayed breeding for many species, making the surveys earlier than ideal. Breeding could be confirmed for only five species, although it was considered probable for another 15 species. Among species for which breeding was confirmed, Canada and Cackling Geese (*Branta canadensis*, *Branta hutchinsoni*), Northern Pintail (*Anas penelope*), and Dunlin (*Calidris alpinus*) are not shown as breeding on Mansel Island by Richards and Gaston (2018).

Only seven species were reported by all four surveys: Cackling Goose, Tundra Swan (*Cygnus columbianus*), King Eider (*Somateria spectabilis*), Long-tailed Duck (*Clangula hyemalis*), Red-throated Loon (*Gavia stellata*), Sabine's Gull (*Xema sabini*), and Herring Gull (*Larus argentatus*). Black-bellied Plover (*Pluvialis squatarola*), American Golden-plover (*Pluvialis dominica*), and Arctic Tern were recorded on all three post-1930 surveys. According to the 2016 survey, the most widespread species (seen in nine or more survey squares) were Canada Goose, King Eider, and Herring Gull. In 1992, 38 pre-flying King Eider ducklings were seen in four separate creches, along with nine adults and the species was the second most widespread on the 2016 survey. These observations suggest that Mansel Island may be an important breeding area for this species. Likewise, Tundra Swan, as well as being seen on all surveys, was the most widespread species reported on the aerial survey in 1984. Mansel Island appears to support a significant population of this species.

Overall, the avifauna of Mansel Island is very similar to that of the better-known Coats Island, immediately to the west (Gaston and Ouellet 1997). Like Coats, it supports Caribou but apparently not lemmings (*Dicrostonyx* and *Lemmus* spp.; Gaston *et al.* 2012). The absence of the latter probably determines the lack of specialist lemming predators, such as Snowy Owl (*Nyctea scandiaca*) and Long-tailed Jaeger (*Stercorarius longicaudus*). The very flat topography, lacking cliffs, may determine the absence of Peregrine Falcon (*Falco peregrinus*) and Common Raven (*Corvus corax*) and the relative paucity of Snow Bunting (*Plectrophenax nivalis*), all common on adjacent parts of mainland Quebec (Gaston *et al.* 1985). However, the breeding of Sabine's Gull and the probable breeding of Red Knot (*Calidris canutus*) on Mansel Island represent the most southeasterly extension of these species' known ranges in Canada (Richards and Gaston 2018).

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Note

Behaviour of a porcupine (*Erethizon dorsatum*) swimming across a small boreal stream

Thomas S. Jung

Department of Environment, Government of Yukon, Whitehorse, Yukon Y1A 2C6 Canada and
Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2H1 Canada; email: thomas.jung@gov.yk.ca; tjung@ualberta.ca

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Abstract

The swimming behaviour of North American Porcupine (*Erethizon dorsatum*) is largely unrecorded, even though much of its habitat is bisected by innumerable rivers and streams. Moreover, the literature is inconsistent regarding how readily porcupines take to the water and how well adapted they are for swimming. I observed a porcupine swimming across a relatively placid and shallow braid in the Klondike River (Yukon, Canada), after it had aborted three apparent attempts to swim at a relatively fast-flowing, deep channel upstream. This observation provides evidence of porcupine swimming across moving water and suggests that they may be reluctant to do so and selective of where they cross rivers and streams.

Key words: Behaviour; *Erethizon dorsatum*; North American Porcupine; swimming

Observations of North American Porcupine (*Erethizon dorsatum*) swimming are rare in the literature, suggesting that it may be uncommon behaviour. Yet, much of their range is within the boreal forest (Woods 1973; Roze and Ilse 2003), which is interspersed and divided by numerous water bodies. The few observations reported involve swimming in ponds and lakes (Dean 1950; Woods 1973; Roze 2009), with no observations of them crossing rivers or streams. An unusual observation of a Bull Trout (*Salvelinus confluentus*) embedded with porcupine quills provided circumstantial evidence of a porcupine swimming in moving water (Cott and Mochnacz 2007).

The willingness of porcupines to swim is unclear, particularly across rivers and streams. Some authorities suggest that porcupines are not averse to swimming (Roze and Ilse 2003; Roze 2009), and that swimming is an important means for them to access seasonal food resources. For instance, there are observations of porcupines feeding on water lilies (Nymphaeaceae) in shallow ponds and swimming to retrieve food items that they then bring to shore to consume (Dean 1950; Roze and Isle 2003). Moreover, their quills may also be adapted, in part, to help them swim; specifically, Roze and Ilse (2003: 376) surmised that "their watertight, sponge-filled interiors aid in floatation, enhancing the porcupine's swimming capabilities". Alternatively, Woods (1973: 4) opined that "they do not like to swim", although he conceded that they have been observed crossing small water bodies. In an early "experiment", Murie (1926: 112) noted:

> One day I tried to make a porcupine swim across a narrow stream. I shoved it toward the water with a stick and intercepted it whichever way it turned. Nothing could induce it to swim, although I almost shoved it bodily into the water. It came straight toward me, rather than cross the stream, and I finally gave up the attempt.

Here, I provide an observation of a porcupine swimming across a small boreal stream and note its apparent indecision in doing so.

While angling on a braid of the Klondike River, ~15 km east of Dawson City, Yukon, Canada (64.059°N, 139.433°W), I observed a porcupine approaching and, eventually, swimming across the river. At approximately 1705 Pacific Daylight Time, on 6 July 2018, an apparently full-grown porcupine emerged from tall shrubs on the far side of the stream. I did not know its age or sex. The porcupine came to the shore (point A in Figure 1) and, after about 15 s of apparently sniffing toward the far shore, it stepped about 30 cm into the stream, immersing its front

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FIGURE 1. Photograph of the site where a North American Porcupine (*Erethizon dorsatum*) swam across a braid in the Klondike River, Yukon, Canada. At sites A, B, and C, the porcupine stepped into the stream but did not cross it; the dashed line (D) indicates where it swam across the stream. Photo: T.S. Jung.

legs. However, rather than swim across the stream, it backed out of the water and sniffed across the stream again. It immediately moved about 6 m downstream and repeated the same actions at point B (Figure 1). The porcupine moved another 15 m downstream along the shore to point C (Figure 1) and again entered the stream, this time without apparently sniffing the far shore, and it waded deeper until its belly and both legs were under water; however, it again returned to the shore within approximately 30 s. The porcupine then moved into the shrubs and was not seen for about 5 minutes. I then observed it ~35 m downstream of point C, at point D (Figure 1), where it entered the water and swam across the stream, after standing in the stream with both legs and its belly under the water for about 1 minute. The porcupine reached the far shore after swimming for about 2 minutes, and then entered the forest on the other bank and was no longer observed.

I do not know why the porcupine crossed the stream. It was on a small island in the Klondike River that was largely covered with willow (*Salix* spp.) and alder (*Alnus* spp.), whereas, the other side of the stream was covered by mature boreal forest, dominated by Balsam Poplar (*Populus balsamifera* L.) and White Spruce (*Picea glauca* [Moench] Voss) trees. It may have been attracted to something not available on the island at that time.

Points A–C, where the porcupine entered the stream but did not cross it, were in the section of the stream with the swiftest water and a relatively deep channel (~1.2 m deep). In contrast, point D (Figure 1), where the porcupine entered and crossed the stream, was immediately downstream of the riffle, and the water there was more placid and only about 0.5 m deep. However, the stream here was about 30 m wide, compared to about 8 m wide at the riffle (points A–C). It appeared that the porcupine was hesitant to enter the stream and cross the riffle and selected a location to cross where the stream was comparatively slow flowing. This observation suggests that porcupines may not be strong swimmers and seek areas with slow-moving water to cross rivers and streams.

This observation is of scientific value from two perspectives. First, to the best of my knowledge, this is the first record of a porcupine crossing a stream or river, despite the fact that this must be relatively common behaviour for porcupines given the innumerable streams and rivers in the boreal forest, even if it is not regularly observed by humans. Second, given the apparent indecision of the animal about whether to cross the stream, this observation suggests that some porcupines may be averse to swimming, supporting the assertion of Woods (1973). In addition, this observation suggests that porcupines may be selective in terms of where they cross rivers and streams, avoiding deep, turbulent water in favour of more placid and shallow sections. Although the porcupine swam across the stream with apparent ease, its head and body were quite low in the water; thus, waves and riffles may pose a substantial risk of drowning. A swift current could also quickly take a porcupine downstream during a crossing into hazards, such as rough water or waterfalls.

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More Mountain Chickadees (*Poecile gambeli*) sing atypical songs in urban than in rural areas

Stefanie E. LaZerte[1,2,*], Kristen L.D. Marini[3], Hans Slabbekoorn[4], Matthew W. Reudink[3], and Ken A. Otter[1]

[1]Natural Resources and Environmental Studies, University of Northern British Columbia, 3333 University Way, Prince George, British Columbia V2N 4Z9 Canada
[2]Current address: Department of Biology, Brandon University, 270-18th Street, Brandon, Manitoba R7A 6A9 Canada
[3]Department of Biological Sciences, Thompson Rivers University, 805 TRU Way, Kamloops, British Columbia V2C 0C8 Canada
[4]Institute of Biology, Leiden University, Sylviusweg 72, 2333 BE Leiden, the Netherlands
[*]Corresponding author: sel@steffilazerte.ca

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Abstract

Urbanization results in novel ecosystems with unique challenges. These may lead to problems during song learning or development and could result in the singing of atypical songs. During studies of Mountain Chickadees (*Poecile gambeli*) and urbanization in British Columbia, Canada, we observed males singing atypical songs along an urbanization gradient. We found that eight of 78 males consistently sang atypical songs and the odds of singing atypical songs increased with urbanization. We explored several explanations including habitat quality, population density, and bioacoustics. Future studies investigating causes and consequences of atypical singing will clarify effects of urbanization on Mountain Chickadees.

Key words: Mountain Chickadee; *Poecile gambeli*; Paridae; communication; atypical songs; urbanization; urbanization index

Introduction

Among songbirds, unusual songs are those that differ from species-specific local song types. These unusual songs may be (a) rarely heard 'special' songs (such as whisper songs), (b) juvenile songs, the result of early song development, (c) uncommon mimicry of other species, or (d) dialectal songs in an abnormal geographic location (Borror 1968). Unusual songs that do not fit these four categories are considered atypical (e) and may be the consequence of errors in learning or developmental problems (Borror 1968).

Occasionally, young males make 'mistakes' when learning their songs. Perhaps they have few tutors, or cannot hear their tutors well, or perhaps their tutors are a closely related species (e.g., Black-capped Chickadees [*Poecile atricapillus*] and Carolina Chickadees [*P. carolinensis*] learn each other's songs; Sattler *et al.* 2007). There may also be developmental problems, as poor-quality habitat can lead to poor-quality songs (e.g., poor-quality Black-capped Chickadee songs appear less dominant to both males and females; Grava *et al.* 2012, 2013a), which, in extreme cases, could be considered atypical. Alternatively, changes to habitat acoustics may result in young males incorrectly hearing their tutors' songs or actively modifying their own song to reduce interference and increase transmission (e.g., Slabbekoorn and den Boer-Visser 2006).

Many situations leading to atypical songs may occur as a result of urbanization. Urbanization creates a novel ecosystem with unique challenges for many species. Among birds, urbanization can lead to changes in habitat quality that may be positive (e.g., increased food availability from bird feeders; Robb *et al.* 2008) or negative (e.g., habitat loss, competition with invasive species, or environmental pollutants; McKinney 2002), and may influence population dynamics. Urbanization can also lead to altered habitat acoustics (e.g., echoes and reverberation from buildings and pavement; Warren *et al.* 2006) and anthropogenic noise pollution, which can interfere with vocal communication through masking of lower frequencies (Patricelli and Blickley 2006; Shannon *et al.* 2015).

Mountain Chickadees (*Poecile gambeli*) live in montane forests in western North America. They are

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found in urban areas, although they occur at lower densities than they do in rural areas (LaZerte 2015; S.E.L. and K.L.D.M. pers. obs.) and may thus be less urban-adapted than Black-capped Chickadees. Here we present a short exploration of the relationship between atypical songs and urbanization in Mountain Chickadees using the combined data from Marini (2016) and LaZerte (2015).

Methods

We analyzed recordings of 78 adult male Mountain Chickadees vocalizing at dawn in the spring during nest-building and egg-laying (2012 through 2015). These recordings were obtained from two studies investigating effects of urbanization: communication and individual condition (Marini *et al.* 2017a, n = 42), and vocal plasticity (LaZerte *et al.* 2017, n = 36). Recordings were made in and around the cities of Williams Lake (n = 12; 52.129°N, 122.138°W), Kamloops (n = 60; 50.676°N, 120.341°W), and Kelowna (n = 6; 49.884°N, 119.493°W), British Columbia (BC), Canada. Each male was recorded a maximum of once per year. We used site territoriality to distinguish among males within a year, but sites in Kamloops were revisited between years. Known duplicate recordings of males (if the male was banded or identified by distinctive atypical singing) were omitted. Habitat urbanization was evaluated as a continuous index (low = rural, high = urban) by comparing satellite Google Earth images (Google Inc. 2012) of territories (defined as a circular area 150 m in diameter around the recording location of the focal male) and scoring the amount of natural vegetation (natural grass or trees) versus urban ground cover (pavement, buildings, or lawn; for more details see LaZerte *et al.* 2017; for scripts and tutorial see https://github.com/steffilazerte/urbanization-index). The lowest habitat urbanization value (−0.95) reflected sites with 100% natural vegetation (no pavement, no buildings, no lawns). The highest value (2.01) reflected sites with only 11% natural vegetation cover, and 89% pavement, buildings, or lawn.

We only included samples with a minimum of five minutes of vocalization and 25 songs (as Mountain Chickadees use both songs and calls during the dawn chorus; McCallum *et al.* 1999; Grava *et al.* 2013b). Part of LaZerte *et al.*'s (2017) experimental protocol involved exposing males to five minutes of experimental noise. Although they found no effect of this exposure on song variation, we excluded all songs recorded during the noise exposure period and in the five minutes following.

Mountain Chickadees in BC typically sing songs with 3–5 notes in descending order (Grava *et al.* 2013b; Figure 1a). We therefore defined songs as atypical if they were monotone (multiple notes sung on a single frequency; Figure 1b top), contained a reverse frequency change (ascending note[s] as opposed to descending; Figure 1b middle), or contained novel notes (e.g., a note with an extreme upwards frequency sweep; Figure 1b bottom). We used categorical designations for songs as opposed to measuring song characteristics because our data were obtained from two prior studies. In one study, songs had been categorized, but there were no compiled data on individual songs. Although atypical songs are unusual, it is not uncommon for an individual to occasionally sing a few atypical songs. Therefore, we classified males as atypical singers only if they consistently sang atypical songs (>80% of all songs recorded were atypical, most males sang <5% atypical songs).

To determine whether the odds of being an atypical singer increased with urbanization, we performed a logistic regression of male singer type (atypical/typical) against the urbanization index using R statistical software (version 3.3.2; R Core Team 2016). We calculated bias-corrected and adjusted (BCa) bootstrap 95% CI for coefficients. We performed 10 000 replicates using the boot package for R (version 1.3-20; Angelo and Ripley 2017). Figures were created using the R package ggplot2 (version 2.2.1; Wickham 2009). Spectrograms were created with Hanning window lengths of 1024 using the R packages ggplot2 and seewave (version 2.0.5; Sueur *et al.* 2008).

Results

Eight of 78 individuals consistently sang atypical songs. Roughly categorizing urban areas as those with an urbanization index greater than the mean (0) showed that 21% of urban males consistently sang atypical songs whereas only 2% of rural males did (Figure 2a).

The odds of a male consistently singing atypical songs increased significantly with the continuous urbanization index (Log odds = 1.10, 95% CI = 0.28–2.30, SE = 0.42, z = 2.61, P = 0.009; Figure 2b); expressed as an odds ratio, for every 1 unit increase in the urbanization index, males were 3.00 (95% CI = 1.32–9.95) times as likely to be atypical singers. The probability of individuals in the most rural habitats being atypical singers was 2.4% (95% CI = 0.3–11.2%). In the most urban habitats, the probability was 39.0% (95% CI = 11.6–68.0%).

Discussion

Consistently singing atypical songs was not common; however, the odds of doing so increased with increasing urbanization. Because these recordings were collected during the breeding period before juveniles were present, it is highly unlikely that atypical songs

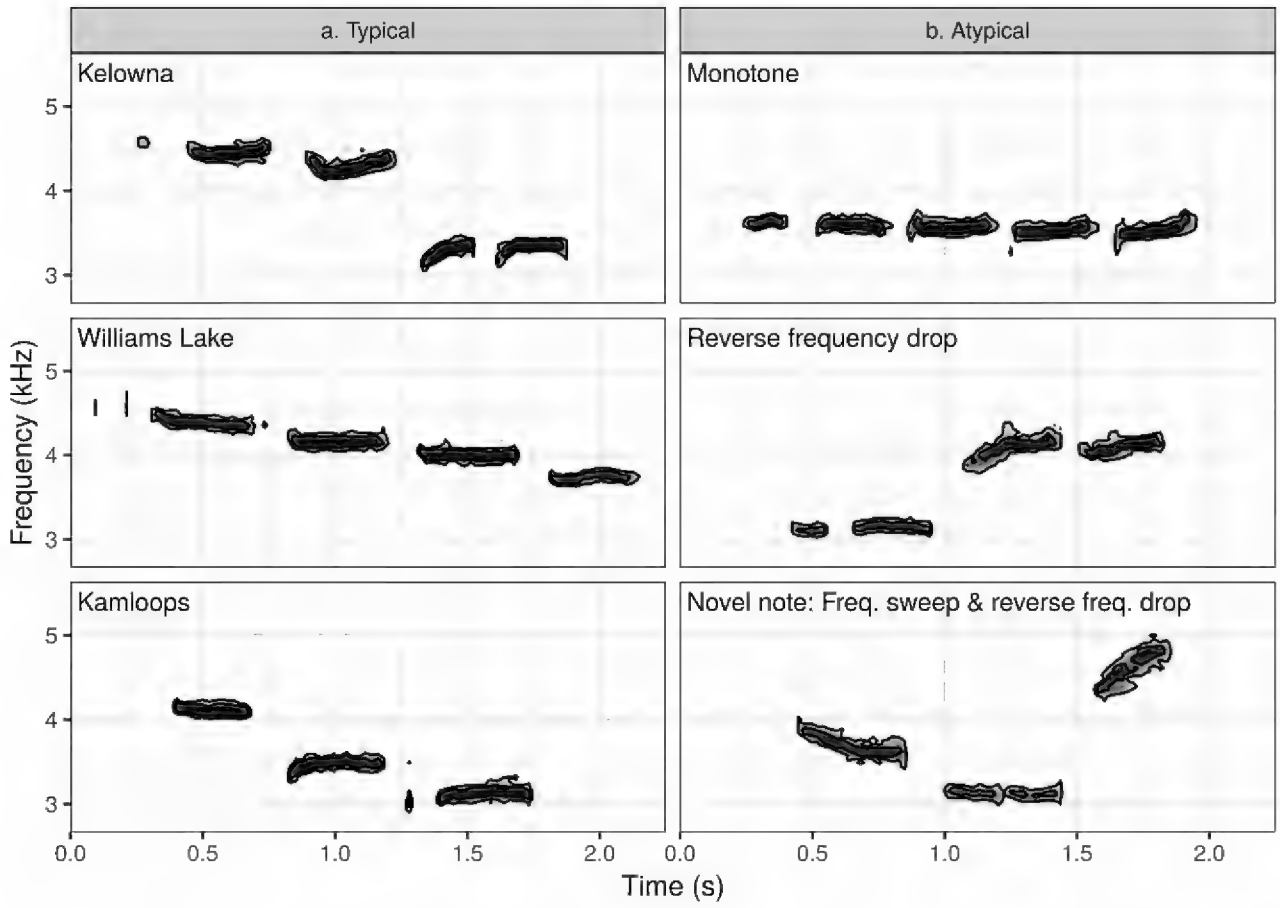

FIGURE 1. Variation in Mountain Chickadee (*Poecile gambeli*) songs in British Columbia, Canada. a. Typical regional variation; all songs show descending frequencies. b. Some examples of atypical songs include monotone songs (top), songs with a reverse frequency drop (middle), and songs with novel notes (bottom).

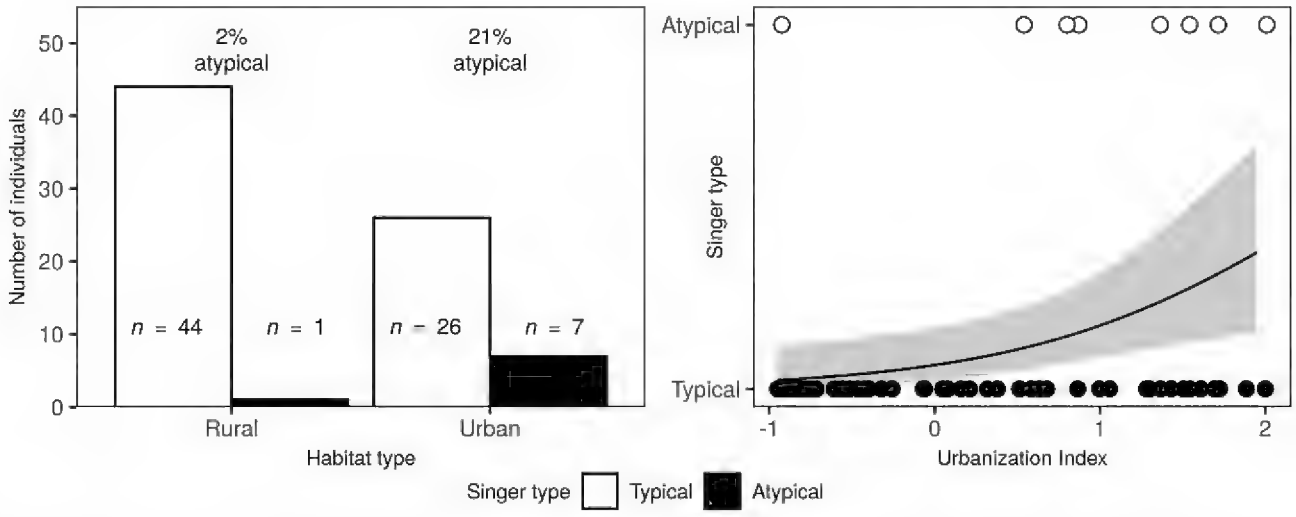

FIGURE 2. Male Mountain Chickadees (*Poecile gambeli*) are more likely to consistently sing atypical songs in urban areas. a. By categorizing urban sites as those with an urbanization index > 0 and rural sites as those with an urbanization index ≤ 0, urban sites show 21% of males singing atypical songs versus 2% in rural areas. b. As urbanization increases, the likelihood of being an atypical singer increases. The line represents the predicted logistic regression, the grey area shows the 95% CI interval around the predicted model. Each point represents a male Mountain Chickadee. The outlier (top left panel b) was recorded in a rural area on the outskirts of Kamloops. There were no sources of water, nor any other obvious sources of noise. It is possibly it could have been a windy location as it was on the side of a hill, but excessive wind was not noted. It was up slope of the train tracks, ~1.5 km away, a distance unlikely to have had an effect. Possibly this individual migrated to the area from an urban area.

represent early song development. Further, as these cities are relatively small (the largest, Kamloops, has a population of 90280; Statistics Canada 2017) and are surrounded by rural habitat, it seems unlikely that birds from different populations (and with different song types) would have exclusively settled in urban areas, or that these urban habitats are isolated enough to facilitate cultural evolution of song (cf. Gammon and Baker 2004; Luther and Derryberry 2012). Consequently, atypical singers in urban areas may result from differences in habitat quality, population density, or environmental acoustics.

Poor-quality habitat may be associated with poor-quality males, either because males in urban habitats do not get enough resources or because only poor-quality males will settle in urban habitats. This, in

turn, may lead to poor-quality song (e.g., nutritional stress hypothesis; Nowicki *et al.* 2002; male quality; Grava *et al.* 2012) which could explain the increase in atypical singers. However, our previous studies of Mountain Chickadees in Kamloops suggest that urban habitat seems to be of at least equivalent quality to rural habitat (Marini *et al.* 2017b). Thus, poor-quality habitat may not fully explain the presence of atypical singers we found.

Mountain Chickadees are less abundant in urban than in rural areas (LaZerte 2015; S.E.L. and K.L.D.M. pers. obs.). In some species, greater urban population densities affect song variation, by influencing male-male interactions (e.g., Eurasian Blackbird [*Turdus merula*]; Ripmeester *et al.* 2010; Great Tits [*Parus major*]; Hamao *et al.* 2011). However, it is unclear how reduced competition could lead to singing atypical songs in Mountain Chickadees. Alternatively, low population density may result in fewer tutors or tutors that are farther away, making it difficult for young chickadees to learn songs correctly (similar to Laiolo and Tella 2005). Further, low densities may also result in the direct introduction of unusual song types by juveniles and less social pressure to conform to local song types (Gammon *et al.* 2005; Gammon 2007).

Urban areas are often noisy (LaZerte *et al.* 2015) and more pavement and concrete leads to altered acoustics (Warren *et al.* 2006). These changes may interfere with vocal communication leading to adjusted songs and/or calls. Male Mountain Chickadees are known to adjust their vocalizations in noisy habitats and in response to noise exposure (LaZerte *et al.* 2017). In a study on closely related Great Tits, Slabbekoorn and den Boer-Visser (2006) found that, throughout Europe, urban males sang more atypical song types (songs with fewer or more notes than the typical 2–4) than rural males, and suggested this could be due to noise interference. If, during song learning, only un-masked and well transmitted aspects of tutor songs are learned properly, changes in bioacoustics could result in atypical songs (Rabin and Greene 2002; Slabbekoorn and den Boer-Visser 2006). Depending on the situation, these atypical songs could be beneficial or detrimental. Atypical songs, which are the result of learning only the least-masked aspects of a normal song (e.g., Mountain Chickadee monotone songs may represent songs which have lost low-frequency notes), could result in less noise-interference and better transmission, and could thus be an adaptation to urban environments. Alternatively, atypical songs may be a symptom of poor learning in urban areas wherein young males settling in urban areas are learning songs incorrectly from tutors that results in poor quality songs.

While atypical songs were uncommon overall, urban Mountain Chickadees in BC were more likely to consistently sing atypical songs than rural males. However, it is not clear whether these songs represent a response to the urban acoustic environment, or a symptom of low population densities. Studies in progress suggest that atypical songs may transmit better in noisier conditions than typical songs (S.E.L. unpubl. data). However, Gammon *et al.* (2005) observed more atypical songs in Black-capped Chickadees in quiet, rural populations as opposed to presumably noisier, urban populations, suggesting a stronger role for population density than urban noise. There are fewer studies on Mountain Chickadees and it is thus less clear how prevalent atypical songs are in more natural landscapes. Possibly, they might be more common than in Black-capped Chickadees, simply because their song varies more among populations than do Black-capped Chickadees (e.g., Grava *et al.* 2013a). Further studies exploring the interaction between noise and population densities (such as in a 2×2 factorial design, varying density of birds and levels of urban noise) could help clarify the potential mechanism. The research could be an observational study or a manipulative experiment (e.g., alter population density through removing birds, use audio speakers to vary the amount of urban noise). It is also unclear what consequences these changes may have on communication or reproductive success, which further studies may also help to clarify.

Author Contributions

S.E.L., K.A.O., and H.S. contributed to the development and design of the LaZerte (2015) study, and K.L.D.M., K.A.O., and M.W.R. contributed to the development and design of the Marini (2016) study. S.E.L. and K.L.D.M. collected data and conducted data cleaning and preparation. S.E.L. conducted the analysis and wrote the manuscript. All authors contributed to development of ideas and commented on draft versions of the manuscript.

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Body mass as an estimate of female body condition in a hibernating small mammal

Caitlin P. Wells[1,*], James A. Wilson[2], Douglas A. Kelt[1], and Dirk H. Van Vuren[1]

[1]Department of Wildlife, Fish, and Conservation Biology, University of California, 1 Shields Avenue, Davis, California 95616 USA
[2]Department of Biology, University of Nebraska, 6001 Dodge Street, Omaha, Nebraska 68182 USA
*Corresponding author: cpwells@ucdavis.edu

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Abstract

In hibernating squirrels, the amount of energy stored as fat may influence several important demographic traits, but is difficult to quantify in living animals. Thus, several non-destructive indices of body condition are used, including simple indices that use body mass and scaled indices that correct body mass for structural size. However, the accuracy of these indices for hibernating squirrels is poorly known. We used measurements of total body electrical conductivity (TOBEC) from adult female Golden-mantled Ground Squirrels (*Callospermophilus lateralis*) to characterize body composition (lean mass versus fat mass) and condition (fat stores) at multiple stages in the circannual cycle. Body mass explained a high proportion of the variation in fat mass during the emergence and pre-hibernation stages, but less during the reproduction stage. Contrary to expectation, correcting for structural size did not markedly improve the condition index. Our results suggest that body mass is a good estimate of body condition during the periods of emergence and pre-hibernation fattening, and therefore may be useful to predict important components of fitness such as reproductive success and overwinter survival.

Key words: Body mass; body condition; condition index; mass-length residuals; fat; ground squirrel; *Callospermophilus lateralis*

Introduction

Seasonal variation in energy supply is a central problem for many mammals, which may respond to periods of environmental energy shortage by storing energy, reducing energy expenditure, or both (Humphries *et al.* 2003). Hibernation, which reduces metabolic demands during winter, is one life-history adaptation to seasonal energy scarcity, but sufficient energy stores are essential to its success (Pulawa and Florant 2000).

In hibernating squirrels, the amount of energy stored as fat may influence several important demographic traits such as overwinter survival (Murie and Boag 1984; Lenihan and Van Vuren 1996), timing of reproductive maturity (Barnes 1984), male breeding effort (Delehanty and Boonstra 2011), female reproductive success (Dobson and Michener 1995; Rieger 1996), offspring sex allocation (Allainé *et al.* 2000), and natal dispersal (Nunes and Holekamp 1996; Neuhaus 2006). Additionally, estimating fat stores is essential for bioenergetic models of hibernation, which can be used to project distribution changes of hibernating species under changing climatic conditions (Humphries *et al.* 2002). However, quantifying body condition (defined here as fat stores, in grams; Kiell and Millar 1980; Dark *et al.* 1989) is difficult to do non-destructively. Because determining the effects of body condition on future life-history outcomes requires that the animal survive measurement, several non-destructive indices for estimating condition have been developed (Schulte-Hostedde *et al.* 2005; Peig and Green 2010). These include simple condition indices that use body mass (e.g., Hock 1960), and scaled condition indices that attempt to correct body mass for structural size (e.g., Reid 1988). Many studies use total body mass as a simple condition index, with the implicit assumption that greater mass reflects greater relative fat stores (Barnes 1984; Sauer and Slade 1987; Lenihan and Van Vuren 1996; Neuhaus 2003; Lane *et al.* 2011). However, larger animals may have greater mass due to larger structural size (skeleton and associated lean tissue) instead of greater fat stores (Dobson 1992). Thus, some studies use a scaled condition index based on residuals derived from a regression of body mass on structural size, with the expectation that correcting body mass by the structural size of an individual improves the estimate of its condition (Bachman 1993; Dobson

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and Michener 1995; Dobson *et al.* 1999; Allainé *et al.* 2000). Positive residuals suggest the animal contains more tissue (presumably fat) than predicted for a given structural size, while negative residuals suggest the animal contains less tissue than predicted for a given structural size.

Scaled indices are appealing because they correct for variance in body mass that is unrelated to energy stores, but available evidence indicates that size-corrected measures do not necessarily improve estimates of body condition compared to use of body mass alone (Krebs and Singleton 1993; Green 2001; Schamber *et al.* 2009). However, most evaluations of condition indices have focussed on mammals that do not store fat for hibernation or energy reserves, and the poor relationship between the scaled condition index and measured fat content may occur because residuals of these relatively lean species primarily reflect differences in protein or water content rather than fat (Schulte-Hostedde *et al.* 2001). Scaled indices might be more appropriate for species in which fat content is a greater proportion of body mass, such as hibernators (Schulte-Hostedde *et al.* 2001), but the predictive ability of simple versus scaled condition indices for hibernating squirrels is poorly known.

Fat storage in hibernating squirrels follows circannual cycles of accumulation and depletion (Buck and Barnes 1999), reflecting seasonal changes in the balance between energy acquisition and expenditure (Kenagy *et al.* 1989). For an index to be an appropriate estimate of body condition, it should explain a high proportion of the variation in fat storage, preferably across multiple stages of the circannual cycle. Adult females are often excluded from condition index validation because of the confounding effect of fetal lean tissue elaboration during gestation (Krebs and Singleton 1993; Schulte-Hostedde *et al.* 2005), yet energetic costs associated with hibernation and reproduction deplete fat stores, and therefore affect body condition, in adult females as well as males (Kenagy 1989; Michener and Locklear 1990; Buck and Barnes 1999). In this paper we use measurements from adult female Golden-mantled Ground Squirrels (*Callospermophilus lateralis*) to evaluate fat stores during four major stages (emergence, reproduction, post-reproduction, and pre-hibernation) in their circannual cycle. Our goal is to assess body mass as a simple index of body condition in each stage, and determine if using a scaled index improves estimates of body condition.

Methods

We studied Golden-mantled Ground Squirrels over three years (2003–2005) in the northern Sierra Nevada mountains of California. These squirrels are locally abundant, medium-sized (200–300 g), and relatively well-known both ecologically and physiologically (Bartels and Thompson 1993).

Our study was conducted in the Plumas National Forest (40.004012°N, 120.810829°W) near Quincy, California, at an elevation of ~2100 m. In this area, adults emerge from hibernation in May and pups are weaned in late July; all squirrels gain weight during September before immerging into hibernation in October. Gestation in Golden-mantled Ground Squirrels is 28 days (Cameron 1967) and weaning occurs when pups reach 30 days old (Phillips 1981). We divided the active season into four circannual stages, defined broadly to encompass individual variation in circannual timing: emergence, 15 May–15 June (emergence from hibernation through mating and early gestation); reproduction, 16 June–31 July (late gestation through lactation); post-reproduction, 1 August–31 August (after lactation but before late summer fattening becomes pronounced); and pre-hibernation, 1 September–early October (when pre-hibernation fattening occurs). Because we did not determine reproductive status for all females in this study, our sample may have included non-reproductive females.

We captured adult female squirrels with Tomahawk live traps (Model 201, Tomahawk Live Trap Co., Hazelhurst, Wisconsin, USA) baited with rolled oats and black oil sunflower seeds coated with peanut butter. Traps were set in the early morning and checked mid-morning. Our methods were conducted according to a protocol approved by the Animal Care and Use Committee of the University of California, Davis, and followed guidelines approved by the American Society of Mammalogists (Sikes *et al.* 2016). At first capture, squirrels were fitted with a uniquely numbered metal tag (Self-piercing fish tag, Style 1005-1, National Band & Tag Company, Newport, Kentucky, USA) in each ear for permanent identification. We attempted to capture all squirrels monthly, but due to differential trapping success not all squirrels were captured each month. We transported captured squirrels to a laboratory near Quincy, where we anesthetized them with an intramuscular injection of ketamine hydrochloride (100 mg/ml). We recorded body mass to the nearest 0.1 g using a portable electronic balance and body length (measured as tip of nose to anus) to the nearest 0.1 cm (Pulawa and Florant 2000). We used body length as a measure of structural size (Bachman 1993; Allainé *et al.* 2000); our measurements of body length showed good repeatability for individuals recaptured in the same stage (Pearson correlation $r = 0.83$, $n = 5$). We quantified body fat using an EM-SCAN SA-3000 body composition analyzer (EM-SCAN, Springfield,

Illinois, USA; no longer available from the manufacturer) to measure total body electrical conductivity. Total body electrical conductivity (TOBEC) is a non-destructive method to analyze the body composition of animals (Scott *et al.* 2001) that has been used to obtain estimates of lean and fat mass from free-living small mammals (Walsberg 1988; Koteja 1996), including ground squirrels (Nunes and Holekamp 1996; Buck and Barnes 1999; Pulawa and Florant 2000). The TOBEC method uses electrical current, which travels differentially through fat versus lean tissue, to generate measures of electrical resistance; resistance measures are then converted to fat mass using species-specific calibration equations (Bachman 1994; Koteja 1996; Walsberg 1998; Scott *et al.* 2001).

EM-SCAN readings are known to vary with animal movement during measurement, differences in gut contents, changes in ambient temperature, and changes in body temperature greater than 4°C (Walsberg 1988; Scott *et al.* 2001). To minimize variation due to movement, we placed immobilized squirrels on a plastic sample tray and lightly restrained them with rubber bands to maintain each squirrel in the same position (dorsoventrally, ventral side down, with the tail tucked under the body). To minimize variation due to gut contents, we only trapped squirrels early in the morning (as foraging began) and did not provide food or water until after TOBEC measurement. To minimize variation due to ambient temperature, we performed measurements in a laboratory at a field station. Anesthesia often causes a drop in body temperature; throughout our study, however, the mean change in body temperature was −1.6 ± 0.3°C (SE), and no individuals lowered their body temperatures more than 4°C. Body composition was calculated as the mean of five replicate measurements; we recorded seven replicate measurements and then discarded the highest and lowest values, though variation in measurements was minimal (coefficient of variation = 0.03). We determined lean mass (M_L) using the calibration curve for Golden-mantled Ground Squirrels:

$$M_L = 18.0 + 0.3M_B + 1.2\sqrt{L_B \times EM}$$

where M_B is body mass, L_B is body length, and EM is the EM Scan measurement ($r^2 = 0.98$; Pulawa and Florant 2000). We calculated fat mass by subtracting lean mass from body mass.

We characterized the body composition (lean mass versus fat mass) and condition (fat mass) of adult female ground squirrels during emergence, reproduction, post-reproduction, and pre-hibernation stages. Because female energetic needs shift throughout the active season from expenditure on reproduction to acquisition before hibernation (Kenagy *et al.* 1989), potentially changing the relationship between body mass and fat mass, we considered each circannual stage separately. We assessed fat stores of 23 adult female Golden-mantled Ground Squirrels; seven were measured in a single circannual stage, six were measured in two circannual stages, eight were measured in three circannual stages, and two were measured in all four stages. Sample size varied by stage, and each female was included only once per stage. If females were measured more than once within the same stage, we randomly selected a single measurement from those taken in the same year ($n = 5$ females), and we considered measures to be independent if taken in different years ($n = 2$ females; Broussard *et al.* 2005). We also tried averaging measurements for the same female within a year, but the results were similar whether we averaged or chose measurements at random. We used analysis of variance (ANOVA) with Tukey's HSD *post-hoc* tests to test for significant differences in mean body length and mean body composition among circannual stages. We used linear regression to examine the relationship between body length and mass by each circannual stage.

Next, we used bivariate linear regression to evaluate the relationship between body mass and fat mass for each circannual stage, and also the relationship between mass-length residuals, calculated from regressing body mass on body length, and fat mass. In addition, because percent fat (fat mass/total body mass) is sometimes used as a measure of body condition in hibernating squirrels (Barnes 1984; Nunes and Holekamp 1996; Neuhaus 2003) we performed the same regressions for percent fat as we did for fat mass. The use of body mass as a variable in both the TOBEC calibration equation and as a predictor of fat mass may introduce some underlying structure to the data, with the potential to inflate the r^2 values. While this is unavoidable, we therefore report r^2 values associated with linear regressions for comparison among stages and indexes, and without associated significance tests (Wasserstein and Lazar 2016).

Finally, because our data contained substantial individual and annual variation in percent fat, which may confound relationships between condition indices and percent fat inferred through linear regression, we fitted linear mixed models with individual female identity and year as random effects, and circannual stage and condition index specified as fixed effects. Models were estimated with Bayesian inference. We used a Bayesian, mixed-effects approach for two reasons: 1) the hierarchical structure of our data suggested the use of mixed effects models that produce more accurate estimates of all parameters, and 2) Bayesian approaches more accurately partition variance among mixed effect parameters than

likelihood-only approaches (McElreath 2016). We developed four models: two with fat mass (in grams) as the response variable, predicted by either mass or mass-length residuals, and two with percent fat as the response variable, predicted by either mass or mass-length residuals. We included all measurements (n = 61) of the 23 adult females in this analysis.

We used a model comparison approach to evaluate the ability of each index to predict fat mass and percent fat. Specifically, we used the Watanabe-Akaike Information Criterion (WAIC) to rank models, based on WAIC differences (ΔWAIC) and Akaike weights. Such values are analogous to other information criteria, where low ΔWAIC values indicate preferred model, and high weight indicates increased probability that the model will successfully predict new data (Gelman *et al.* 2014; McElreath 2016). All analyses were run in R version 3.5.2 (R Development Core Team 2016); we used the packages RStan (Stan Development Team 2016) and rethinking (McElreath 2016) to fit and compare mixed models, and ggplot2 (Wickham and Chang 2013) to plot figures.

Results

Lean mass of adult female Golden-mantled Ground Squirrels varied among circannual stages ($F_{3,51}$ = 3.52, P = 0.02; Table 1), and was lowest at emergence from hibernation and highest before immergence. Estimated fat mass also varied among circannual stages ($F_{3,51}$ = 7.35, P < 0.001), and was lowest at emergence from hibernation and highest before immergence. Percent fat varied among circannual stages ($F_{3,51}$ = 5.90, P = 0.002), and appeared stable throughout the first three stages before showing a sharp increase in the pre-hibernation stage. Additionally, mixed models revealed a generally positive effect of the pre-hibernation stage on fat mass, after controlling for year, individual, and mass or mass-length residual (Table 2).

The relationship between body mass and body length was positive during emergence (r^2 = 0.55, n = 12, P < 0.01), reproduction (r^2 = 0.41, n = 15, P < 0.01), and post-reproduction stages (r^2 = 0.33, n = 16, P = 0.02), but was no longer apparent during the pre-hibernation stage (r^2 = 0.00, n = 12, P = 0.98; Figure 1).

Body mass explained a very high proportion of the variation (93–96%) in fat mass during the emergence, post-reproduction, and pre-hibernation stages, but a lower proportion (84%) during the reproduction stage (Figure 2). Correcting for structural size, as measured by head and body length, did not improve fit within any stage: the proportion of variation explained by mass-length residuals was less than that for the simple index based on body mass during the emergence, reproduction, and post-reproduction stages (57–70%), and equivalent to that explained by body mass during the pre-hibernation stage (96%).

Overall, a similar pattern was evident for the analysis based on percent fat. Body mass explained a moderate to high proportion of the variation in percent fat during the emergence (r^2 = 0.79), post-reproduction (r^2 = 0.69), and pre-hibernation stages (r^2 = 0.91), but a lower proportion during the reproduction stage (r^2 = 0.56). Correcting for structural size did not markedly improve fit within most stages, though mass-length residuals did explain a significant proportion of the variation in percent fat (emergence r^2 = 0.61, post-reproduction r^2 = 0.46, pre-hibernation r^2 = 0.91). Correcting body mass by body length improved model fit only in the reproduction stage (r^2 = 0.86). While both mass and mass-length residuals showed strong positive effects on fat mass and percent fat, WAIC metrics showed a clear preference for the mass models (w_i =1, ΔWAIC=0.0; ΔWAIC for the second model >69 for fat grams and >20 for percent fat; Table 2).

Discussion

Our results suggest that body mass is a useful estimate of body condition during the critical periods of emergence from hibernation and pre-hibernation fattening, and perhaps during the post-reproductive period, supporting the use of body mass as a simple index to predict important components of fitness such as female reproductive success (Rieger 1996) and overwinter survival (Murie and Boag 1984). Body mass

TABLE 1. Mean length and body composition (± 1 SE) of adult female Golden-mantled Ground squirrels (*Callospermophilus lateralis*) near Quincy, California, from 2003 to 2005, by circannual stage.

	Emergence 15 May–15 June	Reproduction 16 June–31 July	Post-reproduction 1–31 August	Pre-hibernation 1 September–1 October
n	12	15	16	12
Mean length (cm)	17 ± 0.4	18 ± 0.3	17 ± 0.3	18 ± 0.3
Mean total mass (g)	158 ± 8.5^{a1}	175 ± 5.3	167 ± 5.9^{a1}	198 ± 9.4^{b1}
Mean lean mass (g)	124 ± 4.8^{a2}	135 ± 3.4	130 ± 3.6	142 ± 4.5^{b2}
Mean fat mass (g)	35 ± 3.9^{a3}	39 ± 2.1^{a3}	38 ± 2.5^{a3}	56 ± 5.1^{b3}
Mean percent fat	21 ± 1.7^{a4}	22 ± 0.8^{a4}	22 ± 0.8^{a4}	28 ± 1.4^{b4}

$^{a\#}$Statistically different value(s) from $^{b\#}$ across circannual stages for that variable, according to Tukey HSD *post-hoc* test.

TABLE 2. Parameter estimates from linear mixed models predicting fat mass (left of dividing line) and percent fat (right of dividing line) of adult female Golden-mantled Ground Squirrels (*Callospermophilus lateralis*), with mass and mass-length residuals used as predictor variables. Estimates in bold indicate fixed effects that are reliably positive. Fixed effects of circannual stage (reproduction, post-reproduction, and pre-hibernation) are compared to the baseline of the emergence stage. Female ID and Year were fitted as random effects with varying intercepts. ΔWAIC values and weights (w_i) are compared between the two models with the same outcome variable.

	Fat grams~mass			Fat grams~MLResiduals			Percent Fat~mass			Percent Fat~MLResiduals		
	Mean ± SD	Lower 0.89	Upper 0.89	Mean ± SD	Lower 0.89	Upper 0.89	Mean ± SD	Lower 0.89	Upper 0.89	Mean ± SD	Lower 0.89	Upper 0.89
Intercept	−35.79 ± 3.36	−40.92	−30.36	40.07 ± 2.70	36.11	43.85	0.77 ± 2.33	−2.68	4.15	22.86 ± 1.65	20.43	25.43
Mass	**0.45 ± 0.02**	**0.42**	**0.48**	—	—	—	**0.13 ± 0.01**	**0.11**	**0.15**	—	—	—
Mass-Length Residual	—	—	—	**0.46 ± 0.04**	**0.40**	**0.52**	—	—	—	**0.14 ± 0.01**	**0.12**	**0.16**
Reproduction	−1.86 ± 1.19	−3.72	0.03	1.36 ± 1.99	−1.86	4.38	−0.25 ± 0.66	−1.29	0.82	0.62 ± 0.77	−0.59	1.85
Post-Reproduction	−1.42 ± 1.30	−3.50	0.63	0.03 ± 2.25	−3.56	3.49	−0.49 ± 0.77	−1.75	0.69	−0.08 ± 0.94	−1.54	1.42
Pre-Hibernation	2.23 ± 1.78	−0.43	5.15	**6.45 ± 2.95**	**2.08**	**11.35**	0.22 ± 1.12	−1.46	2.09	1.29 ± 1.30	−0.71	3.45
ΔWAIC	0.0			69.4			0.0			20.7		
w_i	1			0			1			0		

was less reliable during the reproductive stage, when females likely varied in their reproductive status. Because variation in reproductive status is associated with differences in body composition (Holekamp and Nunes 1989), combining non-reproductive, pregnant, and lactating females likely weakened the relationship between body mass and fat mass; this pattern was more pronounced when condition was defined as percent fat. In pregnant females, increased mass reflects additional lean fetal tissue instead of fat mass (Boswell *et al.* 1994). Reproductive females also vary in litter size (McKeever 1964), and hence fetal mass.

Our study faced two limitations, besides small sample sizes. First, we did not directly measure fat content of squirrels through destructive sampling and chemical extraction. Second, although the TOBEC method has been validated for Golden-mantled Ground Squirrels (Pulawa and Florant 2000), we did not calibrate the TOBEC machine for our population of the species. TOBEC equations derived from one population have been successfully applied to new individuals in another rodent species (Dickinson *et al.* 2001), but the accuracy of TOBEC among populations of ground squirrels is unknown. Consequently, our measurements of fat content are estimates only.

Adult female Golden-mantled Ground Squirrels showed seasonal changes in body composition consistent with other hibernating squirrels, gaining both lean mass and fat mass during the active season (Kiell and Millar 1980; Rickart 1982). Other studies have demonstrated that ground squirrels appear to catabolize both lean and fat tissues to fuel hibernation, but restore these once the vegetative growing season begins (Jameson and Mead 1964; Kiell and Millar 1980; Pulawa and Florant 2000). A late season gain in fat mass is characteristic of hibernating species (Kunz *et al.* 1998; Buck and Barnes 1999; Hilderbrand *et al.* 2000), and it was during this stage that fat mass was best predicted by body mass.

In general, our finding that body mass explained substantial variation (84–96%) in female fat mass is consistent with those of previous studies that combined male and female squirrels: body mass explained 76% of the variation in fat mass in Belding's Ground Squirrels (*Urocitellus beldingi*) collected throughout the active season (Morton and Tung 1971), and 82% of the variation in percent fat in Arctic Ground Squirrels (*Urocitellus parryii*) held in captivity (Lee *et al.* 2011).

Surprisingly, adjusting for structural size using body length did not improve estimates of body condition, except during the reproduction stage for estimates of percent fat. Body length and body mass were linearly related in our squirrels at emergence, supporting the premise that greater mass in some stages was due, at least in part, to larger structural

size. However, the relationship between body length and mass almost disappeared by the pre-hibernation stage (Figure 1). Because the regression of body mass on length had a slope of zero in the pre-hibernation stage, and the magnitude of residuals was equal to relative body mass, the fit of mass-length residuals was identical to that of body mass in this stage.

We suggest three reasons why the scaled index may have performed poorly. First, measures of structural size may be particularly susceptible to measurement error (Yezerinac *et al.* 1992; Blackwell *et al.* 2006; Martin *et al.* 2013). Although we reduced this error by measuring body length on anesthetized squirrels, which are more amenable to measurement than active, unanesthetized squirrels, and this measurement displayed high repeatability within stage, some measurement error remained. Second, measures of structural size such as body length may sometimes be a poor indicator of lean mass that is not associated with energy storage. As with the relationship between body length and total mass noted above, the strength of the relationship between body length

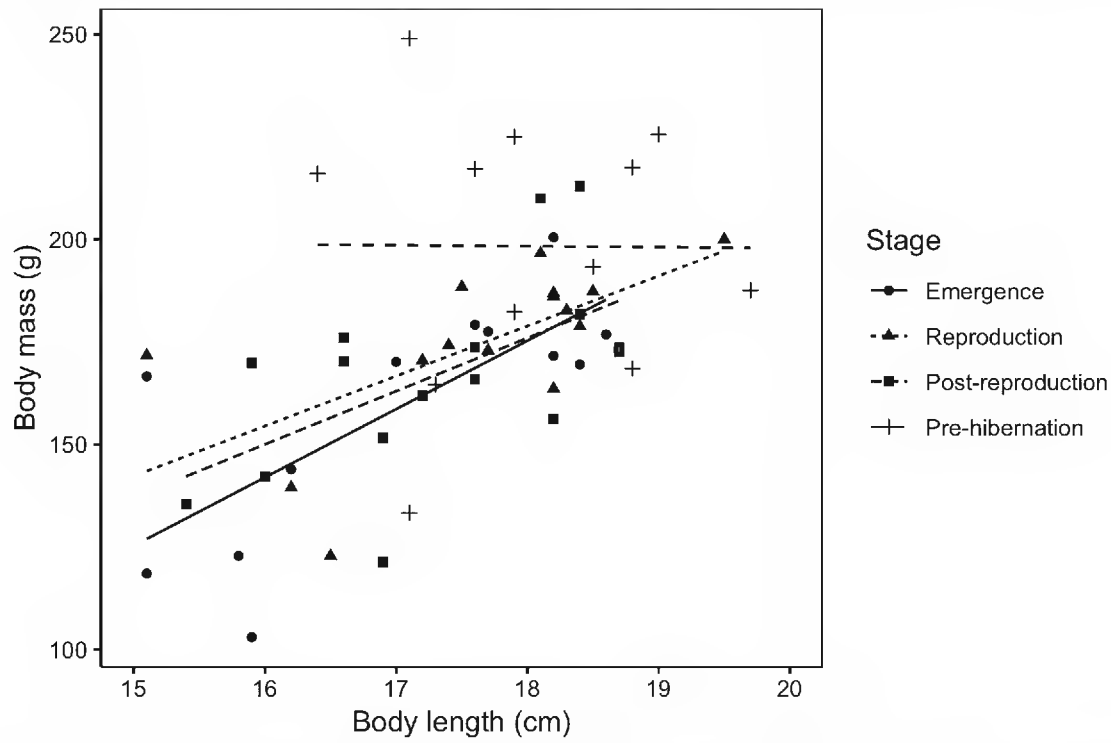

FIGURE 1. Linear relationships between adult female Golden-mantled Ground Squirrel (*Callospermophilus lateralis*) body mass and body length, by circannual stage.

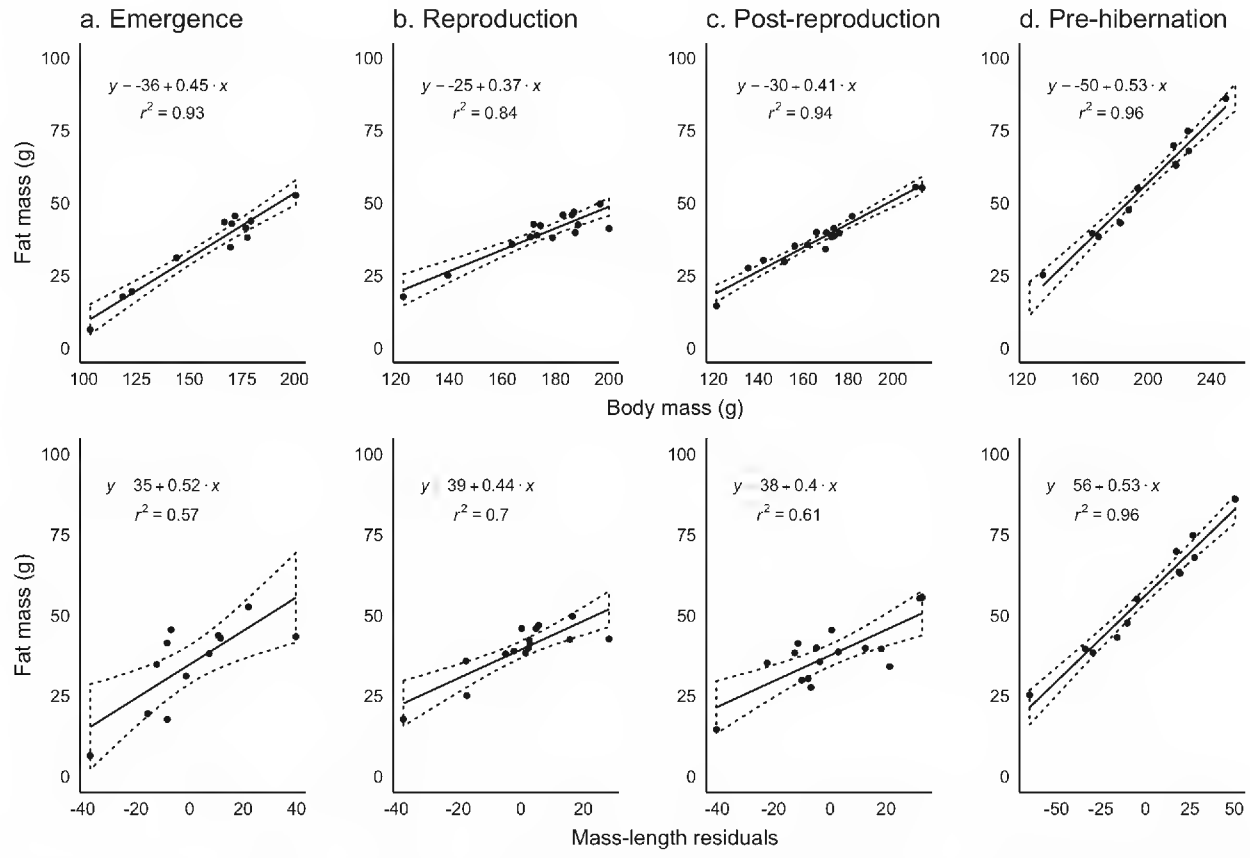
a. Emergence
b. Reproduction
c. Post-reproduction
d. Pre-hibernation
y ~ -36 + 0.45 · x
r² = 0.93
y ~ -25 + 0.37 · x
r² = 0.84
y ~ -30 + 0.41 · x
r² = 0.94
y ~ -50 + 0.53 · x
r² = 0.96
Fat mass (g)
Body mass (g)
y 35 + 0.52 · x
r² = 0.57
y 39 + 0.44 · x
r² = 0.7
y 38 + 0.4 · x
r² = 0.61
y 56 + 0.53 · x
r² = 0.96
Mass-length residuals

FIGURE 2. Linear relationships between adult female Golden-mantled Ground Squirrel (*Callospermophilus lateralis*) total body mass and fat mass (top row), and mass-length residuals and fat mass (bottom row), by circannual stage (columns). Dotted lines represent a 95% CI (two standard errors).

and lean mass declined over the active season (from $r^2 = 0.64$ at emergence to $r^2 = 0.01$ before hibernation). Some individuals that emerged from hibernation with lower body mass than expected for their body size still had substantial fat stores; perhaps these individuals preferentially lost lean mass during hibernation (Pulawa and Florant 2000) to retain fat stores necessary for initiating reproduction. Finally, although body length commonly has been used in ground squirrel studies (Morton *et al.* 1974; Kiell and Millar 1980; Pulawa and Florant 2000), it may simply be a poor measure of structural size. Other studies have used breadth across the zygomatic arches as a measure of structural size (Dobson *et al.* 1999; Viblanc *et al.* 2010). Zygomatic arch breadth has a significant but not especially strong linear relationship with body length for adult females of this species ($r^2 = 0.44$, $P < 0.01$, $n = 18$; C.P.W. unpubl. data), however, highlighting the uncertainty of using a single measure to quantify as complex a trait as structural size.

Body condition is an important trait in the life history of ground squirrels, but measuring condition directly requires sacrificing the animal. Our results suggest that the simple measure of body mass is a useful indicator of body condition, especially early and late in the active season, and that scaled indices do not improve on mass estimates during most stages in the circannual cycle.

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Desiccation of herpetofauna on roadway exclusion fencing

Sean P. Boyle[1,*], Rachel Dillon[1], Jacqueline D. Litzgus[1], and David Lesbarrères[1]

[1]Biology Department, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6 Canada
*Corresponding author: sboyle@laurentian.ca

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Abstract

Significant advances have been made to minimize the detrimental effects of roads on wildlife, but little is known about unintended negative consequences of mitigation strategies. Here, we present observations of adverse effects on herpetofauna of exclusion fencing at Presqu'ile Provincial Park, Ontario. A total of 15 individuals (one salamander, nine anurans, and five snakes) were found dead on unburied fencing, apparent victims of desiccation and/or heat exposure. Air temperatures did not differ between days when dead herpetofauna were and were not found on the fence; however, the fence surface was significantly warmer than the air. Our study shows that fence temperature and design may hinder animals escaping from the road to cooler refugia, and we discuss possible solutions.

Key words: Road ecology; road-effect mitigation; snakes; frogs; Presqu'ile Provincial Park; protected areas; southern Ontario

Introduction

Although herpetofauna are often overlooked compared with other taxa (Andrews *et al.* 2008, 2015; Popp and Boyle 2017), the negative effects of roads on these species are becoming increasingly clear and well documented (Gibbs and Shriver 2002; Andrews *et al.* 2008, 2015; Baxter-Gilbert *et al.* 2015). As a countermeasure, wildlife exclusion fencing (WEF), typically combined with crossing structures, is an increasingly common tool employed by biologists and conservation practitioners to mitigate the effects of road mortality on herpetofauna (Glista *et al.* 2009; Beebee 2013; van der Ree *et al.* 2015). In several instances, WEF has been shown to reduce the number of amphibians and reptiles killed in wildlife–vehicle collisions (Dodd *et al.* 2004; Aresco 2005; Colley *et al.* 2017; Markle *et al.* 2017). However, negative consequences associated with factors other than spatial ecology or road mortality have rarely been attributed to WEF (see Boarman *et al.* 1994; Ferronato *et al.* 2014; Eye *et al.* 2018). Because reducing road mortality is critical to maintaining population viability, WEF has important implications for conservation (Jaeger and Fahrig 2004). As such, documenting and understanding unintended negative consequences of WEF is an important step in conservation efforts.

Although road mortality is a major threat to herpetofauna, care must be taken to ensure that mitigation techniques used to address this threat do not produce undesirable side effects. Unfortunately, potential negative side effects of WEF on individuals and populations are somewhat difficult to predict and may include fence by-catch (Ferronato *et al.* 2014), an increase in the barrier effect (Jaeger and Fahrig 2004), disruption of important movement patterns (Clark *et al.* 2010; Rouse *et al.* 2011), hyperthermia from excessive sun exposure (Peaden *et al.* 2017; Eye *et al.* 2018), and increased road mortality rates resulting from improperly installed or maintained fencing (Baxter-Gilbert *et al.* 2015; Markle *et al.* 2017). Further complicating the matter is the variety of WEF materials, installation methods, terrain, and management regimes, with each combination presenting a unique set of potential side effects (e.g., solid versus mesh WEF; OMNRF 2016; Peaden *et al.* 2017).

In 2013, a six-year project was undertaken in Presqu'ile Provincial Park, Ontario, Canada (43.9944°N, 77.7201°W) to identify the local road-crossing patterns of herpetofauna (Boyle *et al.* 2017) and to test the effectiveness of various strategies to mitigate road mortality and habitat fragmentation. While completing road mortality surveys for this project, we noticed several desiccated herpetofauna on portions of a WEF during its installation. This prompted an investigation to determine whether the installation of the WEF, specifically the possibility that it could expose wildlife to extended periods of heat, was causing mortality of reptiles and amphibians. We hypothesized that if the WEF contributed to mortality associated

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with desiccation, then the fence's bottom lip would be warmer than the air on days when we found dead animals. Second, if desiccation was a result of high temperatures, we expected that either the day or the day before we found desiccated animals on the fence would be warmer than days when no desiccated herpetofauna were found. To inform other road ecology practitioners and to contribute to the improvement of techniques, it is important to document negative secondary effects of various types of WEF and investigate potential solutions.

Methods

The main road of Presqu'ile has a posted speed limit of 40 km/h and an average daily traffic volume of ~3000 vehicles during July and August; thus, this is a high-impact roadway for wildlife (S.P.B. unpubl. data).

Installation of ~1000 m of exclusion fencing (Animex vertical above-ground black exclusion fencing, Knowle, Hampshire, England) began in June 2016 and was completed in August 2016. Fencing was installed ~1 m from the road's edge. The fencing was 0.865 m high and composed of solid, high-density polyethylene (HDPE) sheets, each 16.7 m long. At both the top and bottom of the fence, a lip (0.15 m) was folded over in opposite directions. The bottom lip, folded at a 90° angle toward the road, increased stability of the fence once buried, and the upper lip, also folded at 90° but facing away from the road, was intended to reduce the ability of animals to climb over the fence onto the road. The fencing was installed in two phases: in phase one, the entire fence was fastened against plastic support stakes for stability, with sheets zip-tied together through small holes drilled at either end (20 June to 15 August 2016); in phase two, the bottom lip was buried under 0.10 m of mixed aggregate (mid-August 2016). The addition of aggregate on the road side of the fence precluded the need to bury the fence in a trench, which is costly, labour intensive, and potentially ecologically destructive. On completion, the fence was contiguous except at three intersections (two roads and a bicycle path), where it was curved in on itself away from the road, to create a minimum 5 m turn-around.

We report here observations made during the mid-construction phase (i.e., from the time when the fence was installed until its bottom lip was covered with aggregate) when small vertebrates could move under the fence. Visual encounter surveys were conducted daily by foot beginning at ~0915 along the 1250 m fenced portion of the road from 1 May to 30 August 2016. During surveys, either S.P.B. or R.D. searched the road and roadside for live and dead herpetofauna. No effort was made to detect herpetofauna on the habitat (non-road) side of the fence.

Shaded air temperature at waist height was measured daily along the road at the start of each survey. In addition, we measured air and fence lip surface temperatures using a digital thermometer (Marathon, BA080008, ± 2.0°C, San Leandro, California, USA) each time an animal (alive or dead) was found on the fence. Maximum air temperatures recorded at the nearest weather station, Trenton A, ~20 km northeast of Presqu'ile were also referred to (Environment and Natural Resources 2016).

We completed all analyses in R v.3.4.1 (R Development Core Team 2014). We used Wilcoxon signed rank tests to make three comparisons: (1) air temperature on days in July and August when we found dead herpetofauna versus days on which we found no dead herpetofauna on the fence's bottom lip, (2) maximum temperature of the previous day (Environment and Natural Resources 2016) on days when we found dead herpetofauna versus days when we found no herpetofauna on the fence's bottom lip, and (3) fence temperature versus air temperature when we observed dead herpetofauna.

Results

On 14 July 2016, a dead, desiccated, but undamaged Wood Frog (*Lithobates sylvaticus*) was discovered on the unburied bottom lip (road side) of the WEF. Typically, amphibians that are struck by vehicles sustain moderate to severe visible damage; thus, an apparently undamaged individual was noteworthy. Over the course of surveys, 12 amphibians (10 dead; one salamander and five species of frog; Table 1) and 10 snakes, all Common Gartersnakes (*Thamnophis sirtalis*; five dead; Table 1) were found on the bottom lip of the fencing. Additional individuals were observed before 14 July but no detailed notes were taken. Dead animals all appeared to be mostly intact, but had undergone various levels of desiccation (Table 1). Although not the main goal of our study, it is noteworthy that all of the desiccated herpetofauna were found at previously identified road mortality hotspots (Boyle *et al.* 2017). Of the 10 dead amphibians, all but two were fully desiccated (Figure 1a). The two live frogs detected on the fence behaved normally but appeared to be unable to find a way through the fence, despite the bottom lip being unburied. In addition, one of the live snakes was coiled on the bottom lip of the fence, possibly basking, while the others demonstrated signs of stress (i.e., erratic movements, sluggishness, mouth gaping) possibly because of dehydration.

We did not find differences in air temperature between days we did or did not find deceased herpetofauna ($W = 155$, $P = 0.30$), nor between the

TABLE 1. Reptiles and amphibians observed dead or alive on Animex exclusion fencing in Presqu'ile Provincial Park, Ontario, from 14 July to 30 August 2016, along with demographic and climatic information for each sighting.

Date	Time	Weather	Species*	Sex/lifestage†	Air temperature, °C	Fence temperature, °C	Dead or alive
9 Aug.	0935	Sunny	Blue-spotted Salamander	Juvenile	27.6	31.8	Dead
12 Aug.	0927	Overcast	Gray Treefrog	Juvenile	28.5	32.1	Dead
12 Aug.	0932	Overcast	Gray Treefrog	Juvenile	25.1	35.4	Dead
12 Aug.	0939	Overcast	Gray Treefrog	Juvenile	25.1	35.4	Dead
5 Aug.	0900	Light rain	American Bullfrog	Female	26.7	29.1	Alive
12 Aug.	1339	Overcast	Green Frog	Adult	25.1	35.4	Dead
12 Aug.	1039	Overcast	Northern Leopard Frog	Adult	25.1	35.4	Dead
5 Aug.	0927	Overcast	Northern Leopard Frog	Juvenile	27.3	29.2	Dead
14 Jul.	0940	Overcast	Wood Frog	Juvenile	24.3	27.1	Alive
9 Aug.	0935	Sunny	Wood Frog	Juvenile	27.6	31.8	Dead
12 Aug.	1139	Overcast	Wood Frog	Juvenile	25.1	35.4	Dead
12 Aug.	1239	Overcast	Wood Frog	Juvenile	25.1	35.4	Dead
22 Jul.	0925	Sunny	Common Gartersnake	Adult	24.0	27.2	Alive
15 Aug.	1002	Mostly cloudy	Common Gartersnake	Adult	23.6	27.2	Dead
22 Aug.	1120	Overcast	Common Gartersnake	Adult	21.1	29.3	Alive
2 Aug.	0926	Sunny	Common Gartersnake	Female	23.9	25.6	Alive
23 Aug.	1004	Sunny	Common Gartersnake	Female	24.4	26.9	Alive
17 Jul.	0924	Sunny	Common Gartersnake	Juvenile	21.6	22.6	Alive
29 Jul.	0941	Partly cloudy	Common Gartersnake	Juvenile	26.3	32.1	Dead
2 Aug.	0940	Sunny	Common Gartersnake	Juvenile	23.9	25.6	Dead
2 Aug.	1024	Sunny	Common Gartersnake	Juvenile	28.7	31.9	Dead
5 Aug.	0930	Sunny	Common Gartersnake	Juvenile	26.7	31.2	Dead

Note: Although all individuals demonstrated some desiccation, this was not quantified *in situ*.
*Blue-spotted Salamander (*Ambystoma laterale*), Gray Treefrog (*Hyla versicolor*), American Bullfrog (*Lithobates catesbeianus*), Green Frog (*Lithobates clamitans*), Northern Leopard Frog (*Lithobates pipiens*), Wood Frog (*Lithobates sylvaticus*), and Common Gartersnake (*Thamnophis sirtalis*).
†Snakes designated as "adult" were either not captured or not sexed to minimize additional stress on the animal.

maximum temperatures of days previous to detections versus those without detections (W =156, P = 0.91). However, the fence was significantly warmer than the air (W = 96, P = 0.002; Table 2) on days when dead herpetofauna were observed on the fence.

Discussion

Contrary to our expectations, air temperature was a poor predictor of the presence of dead animals. However, the fence itself was warmer than the air when we found dead herpetofauna, supporting our hypothesis that the fence contributed to the desiccation and mortality. Individuals that moved to the edge of the fence in an attempt to exit the road's right of way would have bypassed the exit path available underneath the fence because of the folded lip. Thus, we conclude that the fence contributed to the observed mortality, likely by reducing the ability of animals to return to cooler refugia.

Consequences of fencing and thermal exposure

Although negative interactions between herpetofauna and exclusion fencing have been previously acknowledged (Boarman *et al.* 1994; Clark *et al.* 2010; Rouse *et al.* 2011; Ferronato *et al.* 2014; Baxter-Gilbert *et al.* 2015; OMNRF 2016), we are unaware of any reports of herpetofauna being found dead or desiccated on the fencing surface. Peaden *et al.* (2017) suggested mesh exclusion fencing may subject herpetofauna to an increased level of sun exposure because of time they spend trying to bypass it. Similarly, Eye *et al.* (2018) suggested increased time spent navigating WEF could be detrimental because of increased heat exposure. We witnessed animals that had breached the fence line, but were unable to return to the habitat side and spent much time walking the length of the fencing trying to find a breach. However, we suspect that solid fencing may partly alleviate the threat of sun exposure (especially in heavily vegetated conditions or on the habitat side). It seems likely that the mortality documented here is the result of extended heat stress leading to hyperthermia and desiccation.

Roads constitute an ecological trap for reptiles because they are attractive for thermoregulation (Andrews *et al.* 2015) and are used as nesting sites by some freshwater turtle species (Steen and Gibbs 2004). Furthermore, if animals that are initially attracted to the road's heat for thermoregulation or nesting opportunities cannot avoid extreme

FIGURE 1. Examples of herpetofauna found dead along the bottom lip (facing the road) of Animex fencing in Presqu'ile Provincial Park, Ontario. a. Heavily desiccated adult Wood Frog (*Lithobates sylvaticus*) with ants scavenging the carcass. b. Partly desiccated adult female Common Gartersnake (*Thamnophis sirtalis*). Note: The unburied bottom lip of the fence is visible in photo b. c. Exclusion fencing buried by approximately 0.1 m of mixed aggregate. The completion of the fence may have contributed to fewer frogs on the road. Photos: Rachel Dillon (a,b), 2016; Sean Boyle (c), 2017.

temperatures by returning to cooler refugia, they risk desiccation and possibly death (Heatwole and Taylor 1987). Although air and fence temperatures were below the thermal maxima of *T. sirtalis* (voluntary = 35°C, critical = 38–41°C; Brattstrom 1965), on some days, these maxima were approached, and the thermal tolerance of snakes decreases if they are dehydrated (i.e., because of prolonged exposure; Ladyman and Bradshaw 2003). Particularly at risk may be amphibians and juvenile snakes because of their higher surface area to volume ratio. Although we cannot estimate how long the individuals we detected were exposed to extreme heat, even a short time could cause heat stress, especially if the individuals were already compromised or dehydrated quickly once on the fence's bottom lip.

Potential sources of bias

We considered alternative causes of mortality. Because we did not observe obvious wounds on the carcasses, mortality from failed depredation is unlikely. Although it is possible that individuals were struck by traffic and subsequently ricocheted onto the fence, this also seems unlikely for multiple reasons. First, individuals were largely undamaged and roughly maintained their shape (Figure 1a,b);

TABLE 2. Average shaded air and fence temperatures recorded on detecting live and dead herpetofauna along Animex exclusion fencing in Presqu'ile Provincial Park, Ontario, in July and August 2016.

Herpetofauna	Air temperature, °C ± SE	Fence temperature, °C ± SE
Living animals		
Amphibians (n = 2)	25.5 ± 1.2	28.1 ± 1.0
Snakes (n = 5)	23.0 ± 0.7	26.3 ± 1.1
Dead animals		
Amphibians (n = 10)	26.16 ± 0.4	33.73 ± 0.7
Snakes (n = 5)	25.8 ± 0.9	29.6 ± 1.3

typically, when snakes and amphibians are struck by cars, they suffer major injuries and are often flattened (S.P.B. pers. obs.). Second, we did not find individuals in the same desiccated condition on the grass or gravel between the fence and the road surface. Third, we saw live frogs and snakes on the bottom lip of the fencing (where we also found the dead individuals), indicating that they used, or at least travelled along the fence, possibly looking for a way to bypass it.

Although our detection rates for dead individuals were likely not 100% (because of scavengers, deterioration, and camouflage), we assumed that the detection probability was equal among all surveys and that detection rate was high because of the slow and methodical nature required for walking surveys specifically targetting small-bodied and often heavily damaged carcasses (Baxter-Gilbert *et al.* 2017). Given that the number of animals we found on surveys (Boyle *et al.* 2017) generally was much higher than the number we found on the fence (reported here), it is also likely that many individuals visited the fence but were able to escape before our surveys and, as such, the risk of thermal exposure and desiccation affects a relatively small proportion of the population.

Precautions and solutions

Although the number of dead animals observed on the mitigation fencing may be inconsequential compared with the road mortality that the fence prevents (i.e., thousands versus dozens; S.P.B. unpubl. data), this likely heat-related source of mortality should be addressed. Exclusion fencing is often installed in areas with at-risk species, where losing even a single individual could have significant consequences for population persistence (Steen and Gibbs 2004). A white version of this fencing, which has a lower heat capacity (Animex International 2016), could be used to limit hyperthermia risk for animals. In many mitigation scenarios, however, white fencing would not be appropriate because of its conspicuousness and increased rate of photo-degradation and consequent reduced lifespan (D. Swensson pers. comm. 8 March 2017).

Although fence temperature may have played a role in the observed mortality, it may be less important than the inability of animals to seek cooler locations. In the summer following our study, several animals were detected along the now back-filled fence line, but none were found dead. Three main differences were apparent between 2016 and 2017: (1) the road side of the fencing had now been back-filled with gravel, reducing access to the road; (2) the weather was much drier in 2016 than in 2017; and (3) vegetation was cut during fence installation in 2016, whereas, in 2017, it had recovered thus providing shade (Figure 1c).

Therefore, to reduce the risk of desiccation of herpetofauna, we recommend that backfilling the fence with gravel be viewed as a time sensitive priority and, when logistically possible, backfilling take place as the fence is installed. In addition, removal of vegetation should not occur during dry periods with high temperatures. Ramps (i.e., one-way jump-outs) built at frequent intervals in the fence to allow animals to exit the road and avoid prolonged heat exposure may also mitigate this issue; however, further investigation is required. Although mortality caused by overheating on fences is not likely to be a major source of population decline, especially when compared to the threat the fence mitigates (i.e., road mortality), it is an example of a conservation action that reduces one threat while potentially creating another and, thus, an additional issue to be considered when planning and installing road mortality mitigation devices.

Author Contributions

Writing – Original Draft: S.P.B., R.D., J.D.L., and D.L.; Writing – Review & Editing: S.P.B., R.D., J.D.L., and D.L.; Conceptualization: S.P.B. and R.D.; Investigation: S.P.B. and R.D.; Formal Analysis: S.P.B. and R.D.

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Monitoring Rock Ptarmigan (*Lagopus muta*) populations in the Western Aleutian Islands, Alaska

Clait E. Braun[1,*], William P. Taylor[2], Steven M. Ebbert[3,4], and Lisa M. Spitler[5]

[1]Grouse Inc., 5572 North Ventana Vista Road, Tucson, Arizona 85750 USA
[2]12841 Nora Drive, Anchorage, Alaska 99515 USA
[3]Alaska Maritime National Wildlife Refuge, 95 Sterling Highway, Suite 101, Homer, Alaska 99603 USA
[4]Current Address: P.O. Box 457, Anchor Point, Alaska 99556 USA
[5]Alaska Maritime National Wildlife Refuge, Aleutian Islands Unit, P.O. Box 5251, Adak, Alaska 99546 USA
[*]Corresponding author: sgwtp66@gmail.com

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Abstract

Knowledge of population fluctuations of Aleutian Islands Rock Ptarmigan (*Lagopus muta*) is limited because of isolation and access. We reviewed the available but limited data on ptarmigan counts on islands in North America and evaluated the use of point counts to estimate changes in apparent numbers of Rock Ptarmigan on three islands (Adak, Amchitka, and Attu) in the Western Aleutian Islands in Alaska. We developed a standardized protocol to count numbers of Rock Ptarmigan (males and females) seen and/or heard on 5-minute point counts at 0.8 km intervals along marked global positioning system routes on Adak (2015–2017), Amchitka (2015), and Attu (2015) islands. Apparent densities based on Rock Ptarmigan seen and/or heard at 98 stops on 10 routes varied and were highest (1.9 birds per stop in 2015, 1.4 in 2016, and 1.0 in 2017) on Adak, lower (0.4 birds per stop) on Amchitka, and lowest (0.0 birds per stop) on Attu in late May–early June 2015. These island populations represent three subspecies and unique conservation units. Continuation of point-count surveys of these three subspecies in future years will provide baseline data over time and lead to a better understanding of any fluctuations in and synchrony among Rock Ptarmigan populations on these islands. This information is necessary for both theoretical (how are ptarmigan breeding populations regulated on islands) and practical reasons (identifying the optimal period for possible translocation to islands where ptarmigan were extirpated by introduced Arctic Fox [*Vulpes lagopus*]).

Key words: Rock Ptarmigan; *Lagopus muta*; Adak; Amchitka; Attu; Aleutian Islands; point counts; Alaska; USA

Introduction

Animal population fluctuations have long been of interest (Elton 1924), especially in insular areas that have no obvious corridors or where populations are otherwise isolated. Rock Ptarmigan (*Lagopus muta*) has a circumpolar distribution in northern latitudes with multiple subspecies: up to 14 in North America alone (AOU 1957; the last time subspecies were listed by the American Ornithologists' Union). Populations of Rock Ptarmigan occupy remote areas and their distribution can be highly fragmented including on islands. Thus, documentation of population fluctuations over time can be difficult. It is important to monitor the status and population changes of species, such as Rock Ptarmigan, and to investigate any underlying factors affecting long-term changes (Pedersen *et al.* 2005; Tesar *et al.* 2016). Measuring changes over time can be problematic in isolated areas such as in the Arctic and substantial efforts to learn how to effectively monitor population status of ptarmigan have been made (Pelletier and Krebs 1997; Bart *et al.* 2011).

There is some evidence that Rock Ptarmigan are cyclic on islands (Iceland; Magnússon *et al.* 2004), but population trends are poorly documented in North America (Weeden 1965; Cotter 1999; Taylor 2013). Peaks in Rock Ptarmigan cycles may represent a 10-fold increase from lows as discussed by Holder and Montgomerie (1993: 15), who cited studies in Scotland (Watson 1965) and Canada (Cotter 1991). Grouse cycles may be correlated with changes in their predator numbers or parasites and not only immigration or emigration from the local population (Dobson and Hudson 1992; Hudson *et al.* 1992; Cattadori *et al.* 2005).

As many as seven to eight subspecies of Rock Ptarmigan have been described from the Aleutian Archipelago, Alaska (AOU 1957). This number has been condensed into four groups (*L. m. evermanni, L. m. townsendi, L. m. atkhensis*, and *L. m. nelsoni*) of which *nelsoni* also occur on mainland Alaska to

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the east (Gibson and Kessel 1997; Montgomerie and Holder 2008). The *evermanni* subspecies occurs in the Near Islands (Attu and Agattu); *townsendi* occurs in the Rat Islands, including Amchitka and Kiska islands, while *atkhensis* occurs in the Andreanof Islands group including Adak, Tanaga to Atka, and possibly other islands. We studied three subspecies (*atkhensis*, *evermanni*, and *townsendi*), all of which are considered endemic groups or unique conservation units (Pruett *et al.* 2010).

Pelletier and Krebs (1997) tested line transect methods to estimate densities of breeding male ptarmigan and concluded they cannot be censused in small areas alone (size of their multiple study sites ranged from 3.0 to 13.5 km^2) as the results were too variable. Others (Brodsky and Montgomerie 1987; Cotter 1999; Watson *et al.* 2000; Favaron *et al.* 2006; Pedersen *et al.* 2012) used methods such as marking and reobservation, point transects, and distance sampling to estimate changes in population size. Bart *et al.* (2011) experimented with use of helicopter and fixed-wing aircraft to survey ptarmigan (and other species) over large areas in northern Canada and Alaska. All of these methods are either labour intensive and/or costly.

The Breeding Bird Survey protocol was developed in the early 1960s to estimate population trends in bird populations over time across large areas and variable habitats in North America (Bystrak 1981; Robbins *et al.* 1986; Droege 1990). It initially used 3-minute count intervals along routes with 50 stops at 0.8 km intervals with routes being surveyed once each year, during the breeding period. More recently 5-minute point counts have been used to better represent population indices of selected species (Ralph *et al.* 1995). All birds (males and females) both seen and heard are recorded at point-count stops.

Male Rock Ptarmigan during the breeding period (late April to early June) are conspicuous (they can range in colour from white to mottled shades of light brown to almost black [Attu] with white bellies and wings), perch up, and make flights from conspicuous sites while calling as they advertise and defend territories (Holder and Montgomerie 1993; Pelletier and Krebs 1997). Males in late May and early June can be solitary or paired with females, which are drab brown (in flight they have white wings) or mottled and inconspicuous in many, if not most, situations (some may be on nests).

Our objectives were to review the available literature on surveys of Rock Ptarmigan on three islands in the Western Aleutian Islands and develop and implement a 5-minute point count protocol to estimate trends in breeding populations of Rock Ptarmigan on Adak, Amchitka, and Attu islands in the Western Aleutian Islands (Figure 1).

Study Area

We reviewed the published and other available literature on Rock Ptarmigan (no other species of ptarmigan occur on these islands) on Adak (51.883°N, 176.65°W), Amchitka (51.35°–51.65°N, 178.617°–

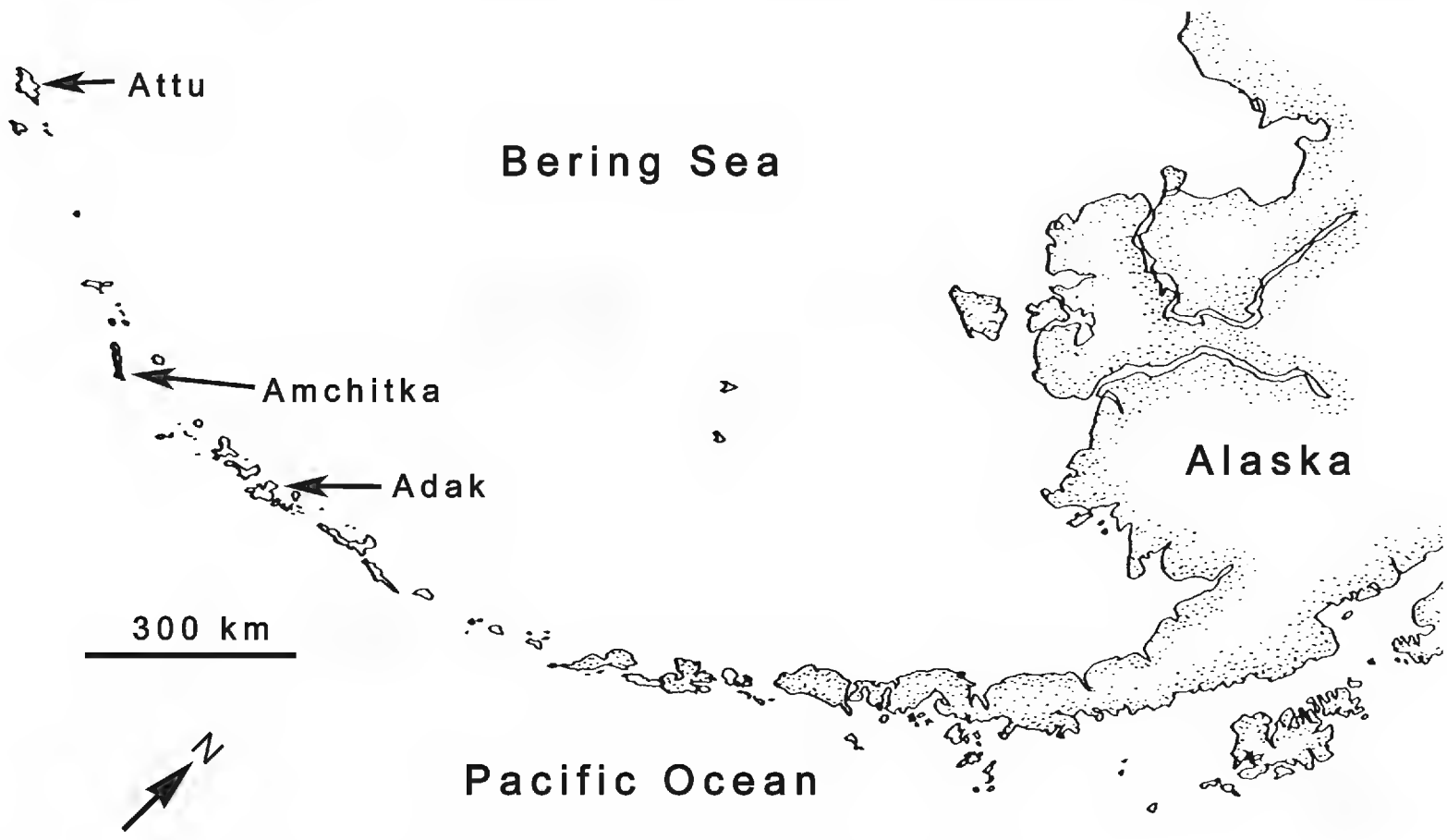

FIGURE 1. Aleutian Archipelago, Alaska showing Adak, Amchitka, and Attu islands.

179.483°E), and Attu (52.85°N, 173.183°E) in the Western Aleutian Islands, Alaska (Appendix S1). Areas surveyed on the three islands by us and others were similar low elevation sites (i.e., marine and stream terraces) adjacent to rarely-used trails (Amchitka and Attu) and occasionally used roads (Adak) that tended to follow coastal areas. The islands vary in size from ~300 km^2 (Amchitka) to 711 km^2 (Adak) and 894 km^2 (Attu). Adak is in the Andréanof group while Amchitka is in the Rat Island group and Attu is in the Near Islands. All are bounded by the North Pacific Ocean to the south and west and the Bering Sea to the north and east. The three islands are distant from each other with Amchitka being 301 km southwest of Adak that is 720 km east of Attu. There are no human residents on Amchitka and Attu and the resident population on Adak is variable and <100 people.

The geology of the three islands is complex with multiple inactive volcanos and volcanic flows as well as past glacial and marine erosion (Coats 1956; Fraser and Snyder 1959; Powers *et al.* 1960). Topography varies from gently sloping marine terraces to undulating tundra ranging to rugged mountains. We surveyed ptarmigan at an elevation of 10 to 300 m on all three islands. Lower and well-drained sites are occupied by grasses and sedges (*Calamagrostis* spp., *Leymus* spp., *Carex* spp.), and low-growing forbs including *Caltha* spp., *Ranunculus* spp., and *Lupinus* spp. with higher slopes dominated by crowberry (*Empetrum* spp.), *Empetrum-Cladonia* tundra, *Cladina* spp. lichens, and other mosses with some low-growing heather (*Cassiope* spp., *Phyllodoce* spp.), willow (*Salix* spp.), and Kamchatka Rhododendron (*Rhododendron camtschaticum* Pallas) shrubs (Amundsen and Clebsch 1971; Everett 1971; White *et al.* 1977).

The climate on all three islands is moist marine with frequent high velocity winds, rain, and fog (Gates *et al.* 1971). Mean daily average temperatures vary seasonally ranging from 0.4°C in January to 11°C in August. Daily (3.9°C in all seasons) and seasonal (9.4°C) ranges in temperature are limited (Armstrong 1971, 1977). Wind speeds are highly variable, and the mean annual precipitation ranges from 83 to 139 cm, depending on the island, with June and July being the months with lowest precipitation (Weatherbase 2015).

Methods

We established and conducted 5-minute point stations (protocol in Table 1) in 2015 following Ralph *et al.* (1995) at 0.8 km intervals along trails and roads on all three islands (dates in Table 2). All routes were conducted using an all-terrain vehicle. Starting points were at trail junctions or easily recognized local features and were recorded as global positioning system coordinates (on file with Alaska Maritime National Wildlife Refuge, Homer, Alaska, USA). Point-count routes were in areas where at least four stops at 0.8 km intervals could be established. There were four routes on Adak with from six to 17 stops, three routes on Amchitka with from four to 21 stops, and three routes with from four to seven stops on Attu (Table 2).

TABLE 1. Protocol for Rock Ptarmigan (*Lagopus muta*) surveys on Adak, Amchitka, and Attu islands, Western Aleutians, Alaska.

5-minute point counts
Count and record all Rock Ptarmigan seen (as male or female) or heard at each point stop. Rarely, the vehicle stopped near a ptarmigan which did not call or flush during the 5-minute count but flushed when the vehicle departed. These birds were included in the count.
Use of two counters is best (one front and one back). A central spot should be chosen.
Consolidate and record totals at end of each point count before returning to the vehicle.
Conduct point-count route prior to 10:00 AM.
Try to avoid high winds (>30 km per hr) and heavy rain.
Adak (use GPS locations at >0.8 km points)
Old Loran Road (10 stops).
Finger Cove (six stops).
Navfac Creek to past Clam Cove (17 stops).
Lake Andrew (six stops).
Amchitka (use GPS locations at >0.8 km points)
Jones Lake/Engineer Road (17 stops).
Charlie-Baker Taxiway south (four stops).
Infantry Road (21 stops).
Attu (use GPS locations at >0.8 km points)
Casco Cove to old airstrips (four stops).
Engineer Hill (top towards Peace monument) from Massacre Creek Beach Trail (seven stops).
Navytown (two stops) to Quonset Valley (four stops).

TABLE 2. Point-count (5-minute) surveys of Rock Ptarmigan (*Lagopus muta*; RP) on Adak, Amchitka, and Attu islands, Alaska, 2015–2017.

Island	Routes	Date	*n* points	RP seen/heard	Birds/Stop
Adak 2015	Finger Bay	29 May 2015	6	6	1.0
	Navfac Creek-Clam Lagoon	29 May 2015	17	12	0.7
	Old Loran Station Road	30 May 2015	10	49	4.9
	Andrew Lake	30 May 2015	6	6	1.0
Mean					1.9
Adak 2016	Finger Bay	18 May 2016	6	3	0.5
	Navfac Creek-Clam Lagoon	3 June 2016	17	16	1.4
	Old Loran Station Road	27 May 2016	10	10	2.1
	Andrew Lake	20 May 2016	6	10	1.7
Mean					1.4
Adak 2017	Finger Bay	1 June 2017	6	0	0.0
	Navfac Creek-Clam Lagoon	29 May 2017	17	16	0.9
	Old Loran Station Road	30 May 2017	10	16	1.6
	Andrew Lake	3 June 2017	3*	4	1.3
Mean					1.0
Amchitka	Infantry Road	9 June 2015	21	12	0.6
	Jones Lake-Engineer Road	9 June 2015	17	3	0.2
	Charlie to Baker Taxiway	9 June 2015	4	0	0.0
Mean					0.4
Attu	Old Loran/Old Runways	3 June 2015	4	0	0.0
	Massacre to Top Engineer	4 June 2015	7	0	0.0
	Navytown to Quonset Valley	4 June 2015	6	0	0.0
Mean					0.0

*High winds did not allow completion or resurveys of three of six routes.

Results

Rock Ptarmigan were heard or seen on all but one (2017 only) point-count routes on Adak and two of three on Amchitka but none was recorded on any of the three point-count routes on Attu (Table 2). However, one ptarmigan pair was seen and four males were heard prior to establishment of point-count routes but not near any of the point-count stops on Attu. Numbers of ptarmigan per stop recorded on point-count routes were highest (1.9, 1.4, 1.0; 2015–2017, respectively) on Adak, lower (0.4) on Amchitka, and non-existent (0.0) on Attu.

Discussion

A literature review of surveys and reports of Rock Ptarmigan on Adak, Amchitka, and Attu Islands revealed that Rock Ptarmigan were mentioned but that few surveys occurred over time with the exception of Amchitka with less information for Attu and Adak (Appendix S1). Large populations were documented for Amchitka (White *et al.* 1977) and Attu (Braun *et al.* 2014) over short periods. Overall, the literature suggests populations of Rock Ptarmigan on the three islands were historically low, especially on Attu.

Our point counts indicate the Rock Ptarmigan population was highest on Adak (2015–2017), lower in 2015 on Amchitka, and very low on Attu in 2015. Our point-count survey data on Attu in 2015 confirmed the ongoing decline on this island reported by Braun *et al.* (2014) from an intensive survey area conducted in 2003–2009. No effort was made to quantify ptarmigan numbers on Attu at higher elevations but ptarmigan were common at lower elevations in 2003–2005 (Braun *et al.* 2014).

The areas that we surveyed on all three islands had similar relief (low marine and stream terraces), were highly disturbed in the mid 1940s and 1950s (Amchitka and Attu) to the late 1990s (Adak), but are now well vegetated with low to non-existent recent human occupation. The three islands have similar predator assemblages (no ground mammals except rats, but with eagles, falcons, gulls, jaegers, owls, and ravens), but we have no estimate of densities. We have no basis to expect that predators (Gilg *et al.* 2003; Therrien *et al.* 2014) affected ptarmigan numbers on the three islands in 2015. We also detected no evidence that male aggressive behaviour was a factor at the densities we observed (Mougeot *et al.* 2003). The possibility that herbivory (Sinclair *et al.* 1988) could affect populations of ptarmigan across islands at substantial distances from each other through plant compounds was considered but was deemed unlikely because of isolation, few deciduous shrubs, and distances involved.

We documented three different levels of abundance of Rock Ptarmigan on Adak (high), Amchitka

(lower), and Attu (very low) in 2015. The apparent, long-term decline on Attu since 2003 (Braun *et al.* 2014) appears to have stabilized from 2009 to 2014 (Braun *et al.* 2014). We agree with the hypothesis of Sandercock *et al.* (2005) that animal cycles in Arctic marine and terrestrial environments are most likely affected by latitudinal gradients in the north and altitudinal gradients elsewhere. The islands we studied are surrounded by the North Pacific Ocean and the Bering Sea and we worked at or below 300 m, thus the birds on these high latitude islands are mostly affected by the marine environment. We further agree that systematic surveys (Tesar *et al.* 2016) to detect trends in breeding populations (Nichols and Williams 2006) of different populations of Rock Ptarmigan are needed at least at 3–5 year intervals for both theoretical and practical reasons and should be able to detect population changes. It is possible that further translocations, similar to the one from Attu to Agattu in 2003–2005 (Kaler *et al.* 2010), may be considered to re-establish populations where they were extirpated by introduced Arctic Fox (*Vulpes lagopus*). Braun *et al.* (2014) documented the immediate recovery of ptarmigan after removal of Arctic Fox. But before such future translocations can be considered, a better survey protocol was needed to determine population status and trends of ptarmigan on these other islands. Knowing when ptarmigan populations may be 'high', especially if they cycle, also would be important so adequate numbers can be captured for immediate release on islands currently unoccupied by Rock Ptarmigan. This should reduce costs and improve chances for success of the transplants. Understanding fluctuations of Rock Ptarmigan populations, if they occur, is also important in the Arctic as the results from studies on islands may have relevance to 'cycles' and management of species of ptarmigan in mainland areas.

Point counts may be the most efficient and least expensive method to obtain standardized data (all birds seen and/or heard) for Rock Ptarmigan in areas with road or trail systems because large areas can be surveyed with few personnel. Early counts (May) should provide an opportunity to record more females than counts in early to mid June when females will be nesting. The three islands of Adak, Amchitka, and Attu each have different Rock Ptarmigan subspecies of conservation importance (Pruett *et al.* 2010) and their population dynamics deserve further study. There is a continuing need for population data to provide insight into whether cycles exist and their periodicity and synchronicity among islands.

Author Contributions

Conceptualization: C.E.B., W.P.T., and S.M.E.; Funding Acquisition: S.M.E.; Investigation: C.E.B., W.P.T., S.M.E., and L.M.S.; Writing – Original Draft: C.E.B; Writing – Review & Editing: C.E.B., W.P.T., S.M.E., and L.M.S.

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SUPPLEMENTARY MATERIAL:

Appendix S1. Historical review of information and previous studies and surveys for Rock Ptarmigan (*Lagopus muta*) on three islands (Adak, Amchitka, and Attu) in the Western Aleutian Islands in Alaska.

The Canadian Field-Naturalist

Note

Japanese Chaff-flower, *Achyranthes japonica* (Amaranthaceae), on the Erie islands, an invasive plant new to Canada

James Kamstra

560 Scugog Line 4, Port Perry, Ontario L9L 1Z8 Canada; email: jkamstra@powergate.ca

Kamstra, J. 2019. Japanese Chaff-flower, *Achyranthes japonica* (Amaranthaceae), on the Erie islands, an invasive plant new to Canada. Canadian Field-Naturalist 133(1): 56–59. https://doi.org/10.22621/cfn.v133i1.2161

Abstract

Japanese Chaff-flower, *Achyranthes japonica* (Miquel) Nakai (Amaranthaceae) was found growing on two islands in western Lake Erie: East Sister Island and Middle Island. These are the first documented reports for this species in Canada, and these locations are approximately 300 km north of the nearest reported observations in southern Ohio. Japanese Chaff-flower is a non-native plant from Asia, which is highly invasive in the United States and has the potential to become so in Canada.

Key words: Japanese Chaff-flower; *Achyranthes japonica*; East Sister Island; Middle Island; Ontario; non-native invasive plant; range extension

During a visit to East Sister Island Provincial Nature Reserve in Lake Erie (Essex County, Ontario) on 27 September 2018, I found a small population of Japanese Chaff-flower, *Achyranthes japonica* (Miquel) Nakai (Amaranthaceae) in the shade of moist deciduous forest co-dominated by American Elm (*Ulmus americana* L.) and Common Hackberry (*Celtis occidentalis* L.; Figure 1). The location was at 41.81230°N, 82.85764°W in the island's interior, at least 100 m from the Lake Erie shoreline. The population consisted of 15 plants, up to 50 cm tall. One specimen was collected.

Two larger and taller stands of the plant were encountered on East Sister Island at ~41.8117°N, 82.8587°W in a small gap in a similar type of forest and at 41.8120°N, 82.8582°W. These were ~50 m from the shoreline. Both stands were more robust and dense than those at the first location, each consisting of several dozen plants over 60 cm tall. They were growing on moist, level ground that may receive seasonal inundation and were partly shaded by Common Elderberry (*Sambucus canadensis* L.) and associated with Stinging Nettle (*Urtica dioica* L.), Common Pokeweed (*Phytolacca americana* L.), Spotted Jewelweed (*Impatiens capensis* Meerburgh), and Dwarf Clearweed (*Pilea pumila* (L.) A. Gray).

On 5 October 2018, I visited Middle Island, part of Point Pelee National Park, also in Lake Erie and situated ~20 km southeast of East Sister Island. I observed two patches of Japanese Chaff-flower on the west end of that island within 15 m of the shoreline. Five plants were at the base of a limestone shingle berm in shade under a moist deciduous forest dominated by Common Hackberry at 41.68366°N, 82.68593°W. There were few other plants in the ground layer. The second larger nearby patch, at 41.68358°N, 82.68620°W, consisted of several dozen individuals. This patch was in semi-shade under forest dominated by Common Hackberry, associated with Stinging Nettle and Common Pokeweed. The island was surveyed quite comprehensively and no other patches of Japanese Chaff-flower were found. T. Dobbie (pers. comm. 3 December 2018) reported finding and photographing a plant that she did not recognize while conducting a plant survey on Middle Island on 8 June 2018. The plant was nondescript with no fruit or flowers because it was early in the season. She sent the photo to me, as I was now familiar with the species, and I confirmed that it was Japanese Chaff-flower, making that the earliest documentation of the species in Canada. Discussions with leading field botanists, the Canadian Food Inspection Agency (C. Wilson pers. comm. January 2019) and a check of the records and specimens available at the herbaria of the Canadian Museum of Nature, Agriculture and Agri-Food Canada, the Database of Vascular

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FIGURE 1. Japanese Chaff-flower (*Achyranthes japonica*) observed on East Sister Island, 27 September 2018. The plant was growing in partial shade. Photo: James Kamstra.

Plants of Canada (VASCAN 2019), and the Ontario Ministry of Natural Resources and Foresty revealed no previous reports of this species in Canada.

Japanese Chaff-flower is native to Japan, Korea, and China, where it is known for its medicinal properties (Jung *et al.* 2007). The first North American record of Japanese Chaff-flower was from Martin County in eastern Kentucky, in August 1981 (Medley *et al.* 1985). Within a decade, the plant had dominated the floodplains in the area where it was first discovered and, within 15 years, had spread over 500 km along the Ohio River valley (Evans and Taylor 2011). The first documentation in Ohio was from 1992 (Vincent and Cusick 1998). In Flora of North America, Robertson (2003) indicated the plant's presence in Kentucky, West Virginia, and Ohio. Evans and Taylor (2011) mapped the distribution in the United States at the time showing that, by 2011, it had been confirmed in every county along the Ohio River from West Virginia to Illinois, with isolated populations in Georgia and Tennessee.

Japanese Chaff-flower is on the watch list for several states including Michigan (Michigan Invasive Species 2018) and Wisconsin (Wisconsin DNR 2018), both states where it has not yet been reported. None of the available mapping shows Japanese Chaff-flower to be currently present near Lake Erie. Both EDDMapS (2018) and iNaturalist (2018) show that the nearest reported observations are in the vicinity of Cincinnati, Ohio, ~300 km south of the Erie Islands. R. Gardner (pers. comm. 22 January 2019), confirmed that, currently, Japanese Chaff-flower has been recorded only from the southern counties bordering the Ohio River in that state.

At first glance, Japanese Chaff-flower superficially resembles Lopseed (*Phryma leptostachya* L.) because of the narrow erect spikes crowded with deflexed fruits and opposite leaf arrangement. However, the flowers of Japanese Chaff-flower have five deflexed tepals, and the ovate-elliptical leaves are glabrous and lack teeth (Robertson 2003). The fruits hang tightly on the spike; each one contains a pair of spiny bracts that adhere to fur and feathers. The seeds are mainly spread by animals or water transport (Evans and Taylor 2011). Japanese Chaff-flower is typically 0.75–1.5 m tall (Robertson 2003), but can reach 3 m (Schwartz *et al.* 2016). Throughout its introduced range in the United States, it most frequently grows in semi-shaded moist soils, but can also occur in drier and sunny sites (Schwartz *et al.* 2016) and is, therefore, capable of colonizing a variety of habitats.

The origin of the plants on the two Erie islands can only be speculated. Middle Island is ~18.5 ha in area and located 4.5 km south of Pelee Island, the

nearest land mass. East Sister Island is ~13 ha in area and more remote at 10 km north of North Bass Island, Ohio, the nearest land mass of more than 2.5 ha. Both East Sister and Middle Islands support large nesting colonies of Double-crested Cormorants (*Phalacrocorax auritus*) numbering in the thousands (McGrath and Murphy 2012) as well as smaller numbers of nesting Herring Gulls (*Larus argentatus*), Black-crowned Night-herons (*Nycticorax nycticorax*), Great Blue Herons (*Ardea herodius*), and Great Egrets (*Ardea alba*; IBA Canada 2018). Because the seeds of Japanese Chaff-flower can readily attach to fur or feathers, the plants may have been carried to both islands by cormorants or other birds. Cormorant nests were present in trees in the vicinity of Japanese Chaff-flower patches on both islands.

Choi *et al.* (2010) examined nearly 4000 birds for the presence of plant propagules on a remote island off Korea. Three species of migratory birds were found to have seeds of Japanese Chaff-flower attached to their feathers, including two marsh species: Eurasian Bittern (*Botaurus stellaris*) and Swinhoe's Rail (*Coturnicops exquisitus*). Choi *et al.* (2010) suggest that birds may have been responsible for the spread of Japanese Chaff-flower to offshore islands in Korea where it has become highly invasive.

Considering the relatively intense floristic survey of the Lake Erie Islands (Duncan *et al.* 2010), it seems likely that Japanese Chaff-flower is a recent arrival. Given that Japanese Chaff-flower is not known from the south shore of Lake Erie (R. Gardner pers. comm. 22 January 2019), it seems likely that birds were the means for its spread onto East Sister and Middle Islands. The sheer abundance of cormorants, which nest all over both islands, make them a likely vector. Japanese Chaff-flower also spreads by water, but the plant is not known to be present elsewhere along the Lake Erie shore. Furthermore, the plants found on East Sister Island were inland and not along the immediate shoreline.

Japanese Chaff-flower has the potential to become an aggressive invasive plant in southern Ontario. Because of the seriousness of this new threat, several fact sheets have been produced to inform the public about control methods and encourage them to report sightings (Evans and Taylor 2011; Rathfon and Eubank 2013; Schwartz *et al.* 2015). The plant has spread rapidly along river systems in the United States and has been identified as a high priority invasive in Indiana (Rathfon and Eubank 2013). A single large plant can produce more than 1000 seeds and 94% of the seeds have been shown to be viable (Evans and Taylor 2011). Infestations can attain densities of more than 70 plants/m^2, which will shade out all other plants below them (Evans and Taylor 2011). They also have the ability to invade undisturbed forests that have not been previously impacted (Schwartz *et al.* 2016).

The United States Department of Agriculture (USDA 2014) has evaluated the plant's weed risk potential and, based on its native range, determined that it can survive in hardiness zones 5–10. Consequently, it has the potential to spread to all of Ontario south of the Canadian Shield, as well as parts of Quebec, the Maritimes, and even parts of British Columbia. The Canadian Food Inspection Agency, Canada's national plant protection authority, is conducting a full risk assessment of the Japanese Chaff-flower to determine its invasive potential in the country (C. Wilson pers. comm. January 2019). Control, research, and ideally eradication should be high priorities before the plant gains a strong foothold, although this may not be possible given its spread in the USA.

Voucher specimens

Canada, Ontario: Essex County, Pelee Township, East Sister Island. 41.81230°N, 82.85764°W. About 15 plants growing in moist soil in deciduous forest co-dominated by American Elm and Common Hackberry, 27 September 2018, *CAN-10091002* (CAN).

Canada, Ontario: Essex County, Pelee Township, Middle Island, Point Pelee National Park. 41.68358°N, 82.68620°W. About 35 plants growing in moist soil near shoreline in deciduous forest dominated by Common Hackberry, 5 October 2018, *CAN-10091001* (CAN).

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Michael J. Oldham of the Natural Heritage Information Centre provided literature references and many useful comments and reviewed the draft. Dr. Tony Reznicek from the University of Michigan initially identified the plant from photographs and reviewed the draft. Y. Robert Tymstra accompanied me on field visits and also searched Middle Sister Island for the plant. Tammy Dobbie sent photographs and details about plants that she observed on Middle Island. Richard Gardner, chief botanist with the Ohio Department of Natural Resources, provided information on the species in Ohio. Claire Wilson, with the Plant Health Risk Assessment Unit of the Canadian Food Inspection Agency, provided comments from the perspective of that agency.

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Gray Wolf (*Canis lupus*) recolonization failure: a Minnesota case study

L. David Mech[1,*], Forest Isbell[2], Jim Krueger[3], and John Hart[4]

[1]United States Geological Survey, Northern Prairie Wildlife Research Center, 8711 – 37th Street SE, Jamestown, North Dakota 58401-7317 USA
[2]Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, Minnesota 55108 USA
[3]Cedar Creek Ecosystems Science Reserve, University of Minnesota, East Bethel, Minnesota 55005 USA
[4]United States Department of Agriculture, Wildlife Services, Grand Rapids, Minnesota 55744 USA
*Corresponding author: mechx002@umn.edu

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Abstract

During the past few decades, Gray Wolves (*Canis lupus*) have recolonized many areas in the United States and Europe. In many other cases, however, although dispersing wolves reached areas with adequate prey, a population failed to recolonize. Herein, we provide a case study detailing how a wolf pack attempted for three years to recolonize an area 55 km from a long-established population and within 25 km of Minneapolis and St. Paul, Minnesota, but failed. The pack produced three litters of pups and at one time included 11–19 members, but it preyed on livestock and dogs and, consequently, was lethally removed. The history of this pack's attempt to recolonize an area long devoid of wolves exemplifies the issues that have prevented earlier recolonizations in non-wild lands in Minnesota and elsewhere and that promise to do so well into the future.

Key words: *Canis lupus*; depredation; distribution; Gray Wolf; livestock; recolonization

Introduction

During the past several decades, Gray Wolves (*Canis lupus*) have been recolonizing many areas of the world (Boitani 2003; Chapron *et al.* 2014; Mech 2017). In the contiguous United States, they have recolonized Wisconsin, Michigan, the northwestern USA, and new areas of Minnesota, and are dispersing into adjacent states (Mech 2017). Biologically, wolves are prolific and can survive anywhere with sufficient food. Because they can subsist not only on prey but also on carrion and even garbage, the only constraints on where they recolonize are anthropogenic factors, including vehicle strikes, legal harvest, illegal killing (including poisoning), and legal livestock-depredation control.

Humans persecuted wolves throughout much of their original range; thus, those that survived lived primarily in wilderness or areas with low human density. That gave some biologists the impression that wilderness was required for their survival, and early models to predict potential wolf habitat in the Upper Midwest made that assumption (Mladenoff *et al.* 1995, 1999, 2006), although it was later challenged (Mech 2006a,b). Eventually the models were refined (Mladenoff *et al.* 2009) to reflect the fact that wolves do not require wilderness (Mech 2015). However, to survive and repopulate a new location for multiple generations, wolves do need to avoid areas and behaviours that bring them into conflict with human activities (Erb and Don Carlos 2009; Mech 2017).

In Minnesota, wolves have been expanding their range from a wilderness reservoir in the northeastern part of the state. Since the early 1970s, they have been gradually recolonizing westward and southward toward semi-wilderness, agricultural areas, and a major metropolitan area (Fuller *et al.* 1992; Erb and Don Carlos 2009; Erb *et al.* 2017). As their numbers and distribution have increased, so have depredations of livestock and the number of wolves killed for livestock-depredation control (Mech 1998; Harper *et al.* 2005; Ruid *et al.* 2009). By 1997–1998, the annually estimated Minnesota wolf population of 2445–2856 had reached the extent of its current distribution (Figure 1) and has since failed to further recolonize the state (Berg and Benson 1999; Erb *et al.* 2017).

Individual maturing male and female wolves have dispersed far and wide from their northern Minnesota reservoir to all parts of the state and have entered nearby states including Wisconsin, Michigan, South Dakota, and North Dakota (Fritts and Mech 1981; Gese and Mech 1991; Merrill and Mech 2000). To recolonize a new area, unrelated males and females

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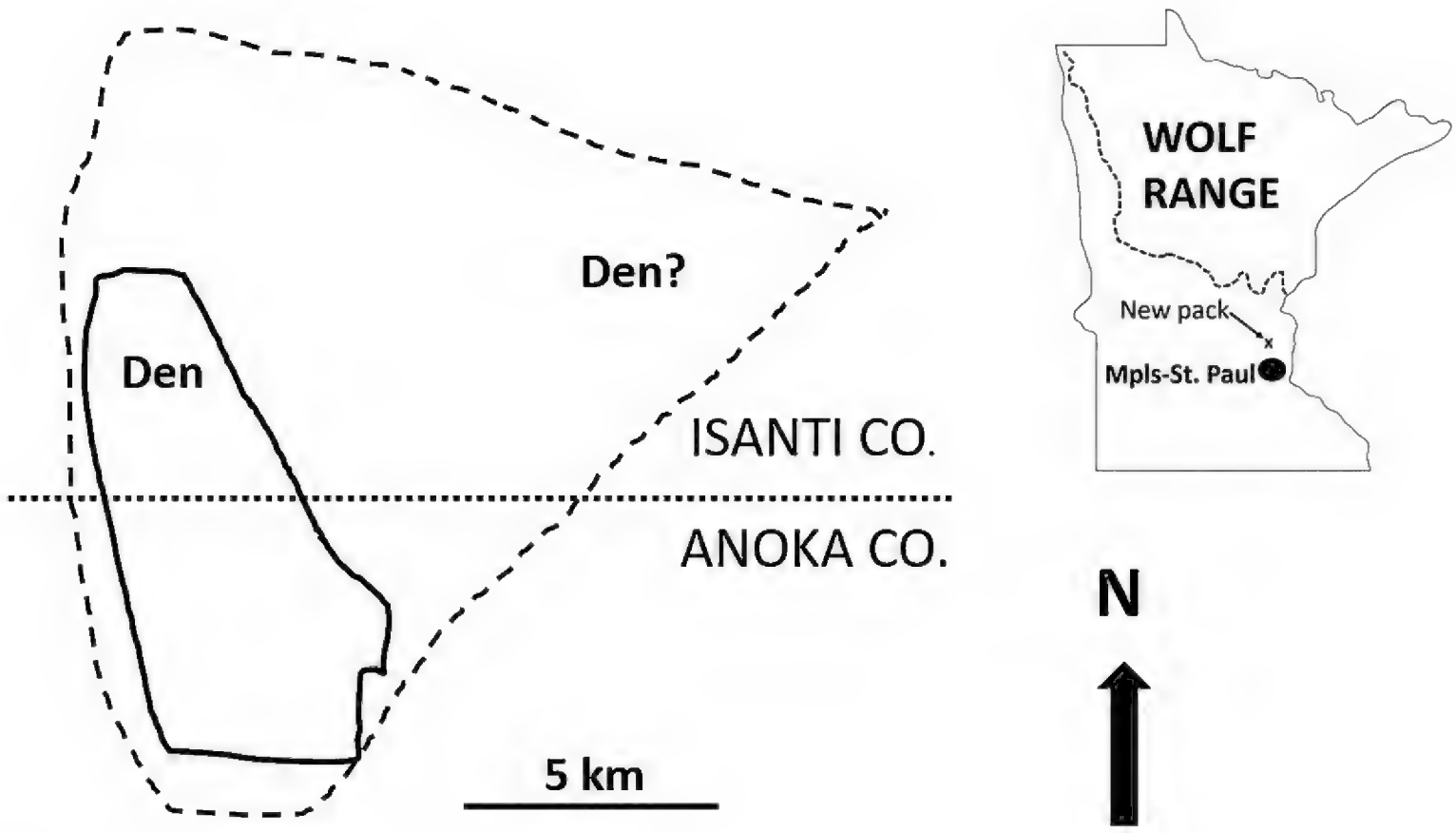

FIGURE 1. Study area where the Isanti Gray Wolf (*Canis lupus*) pack attempted to recolonize. Dashed line connects outermost locations where wolf signs were found and represents the minimum area the pack used from 2014 through 2017. Solid line represents approximate boundary of the Cedar Creek Ecosystem Science Reserve.

must find each other in a suitable location, establish a territory there, pair bond, produce pups, and survive for several years. If pets or livestock are available locally, resident wolves often begin preying on them. Such depredations decrease human tolerance of wolves (Williams *et al.* 2002; Karlsson and Sjostrom 2007; Olson *et al.* 2015), and state and/or federal wolf depredation control agencies often lethally remove them or translocate them depending on applicable laws. Thus, wolves are only able to recolonize areas with low human presence.

In Minnesota, wolves have attempted to recolonize and establish a breeding population southward ~25 km north of the Minneapolis–St. Paul suburbs, at about 45°43′N (Erb and Don Carlos 2009; Erb *et al.* 2017). During 1997, a pack or pair was recorded about 45 km west of there near the Sherburne National Wildlife Refuge (Berg and Benson 1999), but by 2004 that pack no longer existed for reasons unknown (Erb and Benson 2004). In 2010–2011, a new pack survived for two years about 25 km south of the current wolf range, but two adults, a yearling, and four pups were then lethally removed for depredation control.

In 2014, a new pack (the Isanti pack) formed 55 km south-southeast of the current wolf range, and within 25 km of the Minneapolis–St. Paul suburbs in an area with 0–10% chance of wolf recolonization according to the latest wolf habitat models, which consider road density and agriculture (Mladenoff *et al.* 2009). This article details the 3-year attempt by wolves to recolonize that area.

Study Area

The study area (at about 45°27′N, 93°08′W) comprises ~80 km^2 in northern Anoka and southern Isanti counties in east-central Minnesota (Figure 1). Most of the area is rural residential and agricultural, interspersed with patches of uninhabited lowland and woodlots, the largest being the University of Minnesota Cedar Creek Ecosystem Science Reserve (CCESR) covering about 21 km^2. Roughly 50–60% of the study area is open agricultural fields, and the area is heavily roaded; the most remote location in the area is 1.54 km from the nearest road. Much of the known territory of the Isanti pack fell in Athens township, which had a 2016 population density of 24 people/km^2 (Towncharts 2018) and Linwood township with a density of 62 people/km^2 (calculated from the township area of 84.992 km^2 and the 2016 total population of 5284; American Factfinder 2019). Estimated pre-fawning White-tailed Deer (*Odocoileus virginianus*) density for this area of the state in 2016 was 8.5 deer/km^2 (D'Angelo *et al.* 2016), and Wild Turkeys (*Meleagris gallopavo*) were common. Small herds of cattle are widely scattered throughout the study area. Some 9452 cattle, including calves, occupied Isanti County (1157 km^2) in 2012 (USDA 2012). Domestic dogs are common, and some are free-ranging.

Methods and Results

The first record of wolves having bred in the study area was a trail camera photo of three and possibly four adult-sized wolves during winter 2014–2015. Although a pair of wolves can form at any time, a pair with at least one other adult-sized wolf in winter would almost certainly indicate that the pair had established a territory and produced at least one pup, most likely in the previous spring (Mech and Boitani 2003). There was also a report of a Coyote (*Canis latrans*) trapper catching a wolf in the area in winter 2014–2015.

During summer 2015, wolves denned on the CCESR within 1.4 km of an occupied residence and produced at least eight pups that were observed and photographed several times. Throughout summer, researchers associated with the reserve frequented areas within 100 m of the den multiple times a week during the course of their previously established research. During autumn 2015, nine wolves were seen twice on CCESR property and, in November 2015, 11 (which could indicate that nine pups were produced). In mid-January 2016, a Coyote trapper captured and released a wolf from a snare just outside the CCESR.

In mid-winter 2015–2016, L.D.M. drove the roads throughout the study area and found several places where, between 1 January and 6 February 2016, up to eight wolves had crossed. The greatest distance between locations where wolf tracks, or in one case wolf fur on a barbed-wire fence, were found was 14 km, with the centre of that area being 5.5 km from the 2015 den (Figure 1). By calculating the area enclosed by all the locations where such wolf sign was found, we estimated that the minimum area used by this wolf pack was 80 km^2.

From August 2015 to April 2016, within the area covered by these wolves, three cattle were killed and one wounded, and three dogs were killed by wolves (Table 1). Thus, in April 2016, Wildlife Services, the federal government's depredation control agency (Ruid *et al.* 2009), lethally removed three male wolves, weighing 35, 42, and 47 kg.

Trail cameras on the CCESR continued to record wolf presence throughout summer 2016. In June, wolves killed a 91-kg calf, and Wildlife Services lethally removed a 36-kg male wolf, a 27-kg yearling female, and a 32-kg breeding female from the study area; sign of additional adult wolves remained. Four pups were captured alive during depredation control in late June and released on site according to United States Fish and Wildlife Service requirements that all young of the year be released before 2 August when wolves are protected by the *Endangered Species Act* as they were in 2016. One pup was dead in a snare so could not be released.

Local residents had reported seeing up to eight pups nearby before this. Because the 2015 den at the CCESR was unused in 2016, and trail cameras on CCESR failed to indicate concentrated wolf use of the CCESR, the 2016 den was very likely off CCESR property. Based on where the five pups were caught in late June 2016, on reports of local residents, and on the nearest remote area, we judged that the 2016 den was about 10 km east-northeast of the 2015 den.

During autumn 2016, trail camera photos indicated that at least one wolf still used the study area, and, in May 2017, wolves killed another calf in the same area as the 2016 depredations; Wildlife Services lethally removed a 32-kg male wolf and a 26-kg, non-breeding female. Since 2015, all but one complaint of wolves attacking livestock or dogs in this area were verified by authorities. As of February 2019, CCESR trail cameras have recorded only a single wolf.

TABLE 1. Estimated numbers of Gray Wolves (*Canis lupus*), verified complaints, and numbers of wolves removed by year for the Isanti pack, Minnesota.

	2014	2015	2016	2017
Estimated number of wolves in Isanti pack				
Adults/yearlings	2	3	11	3
Pups	≥1	8	8	0
Total	≥3	11	19*	3
Number of verified complaints				
Dog complaints	0	2	1	0
Livestock complaints	0	1	2	1
Total	0	3	3	1
Number of wolves removed				
Adults/yearlings	0	0	6	2
Pups	0	0	1	0
Total	0	0	7†	2

*Assumes eight pups were born in early April before three adults were lethally removed later in that month.
†In addition to the seven wolves removed, four wolf pups were captured and released on site according to United States Fish and Wildlife Service guidelines because they were caught before 2 August.

Discussion

Although wolves have recolonized much of the northern half of Minnesota as well as many areas of Wisconsin and Michigan over the last few decades, they have failed to recolonize many other adjacent areas with adequate natural prey. These latter areas are those with considerable populations of people and domestic animals. However, it is not for lack of trying (Mech 2017).

This case history illustrates the details of how and when wolves begin to establish in areas with livestock and dogs, they may begin treating these domestic animals as natural prey. This usually happens soon after the wolves start reproducing, especially when a third age class is present. Domestic animals are easy targets because they can nearly always be found in the same place, unlike most natural prey, which require hunting down. The increase in domestic animal depredations with the presence of a third age class or a larger pack (Bradley *et al.* 2015) may result from reduced natural local food resources and more dependent wolves to feed.

Regions similar to our study area were predicted to have probabilities of wolf recolonization of 0–10% (Mladenoff *et al.* 1995, 1999, 2006), and our findings explain why. Wolves can and do inhabit these areas (Mech 2006a,b) but tend to persist longer in wilderness and wild lands where they conflict much less with human interests (Mech 2017). Given the great variation in land use across large areas, gradients of wolf-recolonization suitability exist; thus, along the frontiers of established wolf populations, wolves will continue to attempt to expand into areas with higher predicted probabilities of recolonization, with varied results.

The large body masses of the wolves captured in this study area showed that their lack of success in recolonization and their predation on domestic prey were not because they were desperate for food. All the wolves caught were in excellent condition. Four of the eight were above average for wolves feeding on all-natural prey (Mech 2006c), including the 47-kg male that weighed more than all but two of 873 captures of Minnesota wolves on a natural-prey diet (L.D.M. and S.B. Barber-Meyer unpubl. data).

Despite living among people and livestock close to the suburbs of Minneapolis and St. Paul, the Isanti wolf pack was able to use small areas away from humans to den and raise their young and, in that way, persist for at least three years. Like so many other wolf attempts to recolonize similar areas of Minnesota and other states, this one nevertheless failed because of the conflict that often results from wolves living close to areas with high densities of people, livestock, and pets. Wolf survival in the long term requires large areas of extensive wild lands (Young and Goldman 1944; Mech 1970, 2017; Ruid *et al.* 2009). This case study details why.

Author Contributions

Writing – Original Draft: L.D.M.; Writing – Review & Editing: L.D.M., F.I., J.K., and J.H.; Conceptualization: L.D.M. and F.I.; Investigation: L.D.M., F.I., J.K., and J.H.; Methodology: L.D.M., F.I., J.K., and J.H.; Formal Analysis: L.D.M.; Funding Acquisition: L.D.M. and F.I.

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The Canadian Field-Naturalist

Book Reviews

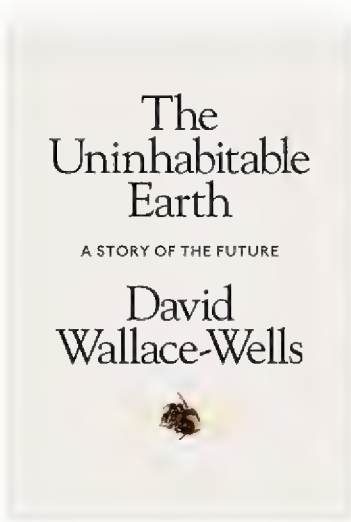
Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes: CAD Canadian Dollars, USD United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

Climate Change

The Uninhabitable Earth: Life After Warming

By David Wallace-Wells. 2019. Tim Duggan Books, Penguin Random House. 320 pages, 27.00 USD, Cloth.



"We run carelessly over the precipice after having put something in front of us to prevent us seeing it." —Blaise Pascal, *Pensées* (1623–1662)

I can summarize this review in a single sentence. Everyone should be compelled to read this book to truly appreciate the nature of the threat from climate change.

David Wallace-Wells lays out in elegant, yet blunt, language the nature and potential extent of the inevitable disruption to humanity from climate change. The threat is ubiquitous and inexorable, it is occurring now, accelerating much more rapidly than we think, and the outcome is, to quote from his opening sentence, "worse, much worse, than you think" (p. 3). Our response to this horrific scenario has been and continues to be inadequate. One can read all manner of apocalyptic claims about climate change and less dire public warnings from the climate scientists themselves who fear to sound alarmist. These proclamations are always couched in sugary dribbles of "but there is still hope". Most of this hope emanates from ignorance and from the belief that the calamity is far down the arrow of time and can be alleviated by technology. Wallace-Wells puts paid to this dream by noting the rapidity with which the current 1.1°C and causal doubling of atmospheric CO_2 have occurred. I worked it out; 90% of greenhouse gases have been accumulated since Bob Dylan was born, and 80% since he sang the "The Times They are a Changin". In one baby boomer generation, this catastrophe has occurred.

This book starts with one stunning fact after another and never falters through 225 pages of text. It leaves one breathless and raw. In Section 1, "Cascades", Wallace-Wells describes the cascading effects of climate change, emphasizing the interconnectedness of our earthly paradise. He reminds the reader of the five great mass extinctions and points out that four of them involved increases in greenhouse gases and warming temperatures of up to 5°C. But these events took thousands or even millions of years to develop, we have only had Dylan's lifetime. Mind you, we have known since the mid-19th century that the simple fact of adding certain gases to the atmosphere would warm the planet, but until recently the idea that we would release hundreds of millions of years of accumulated hothouse carbon in just one century never really sank in. Indeed, for 30% of the population, it is still fake news. Wallace-Wells is Al Gore on steroids and presents an endless mass of facts from every facet of our earthly sphere, and yet we still act as though climate change is something distant, to be fixed by recycling, getting a smaller car, becoming vegetarian, and all manner of single issue fixes that most people resist and resent. Why? Because we can't easily grasp the big picture: the frailty of permanence, the cumulative impact of eight billion of us and our fossil fuel technologies. And thus, we are doing too little.

Section II, "Elements of Chaos", is a series of chapters on specific disastrous effects of climate change, such as heat, hunger, drowning, wildfire. I

won't try to recount the terrors that Wallace-Wells chronicles, there are far too many. Suffice to say these make depressing and startling reading. Section III, "The Climate Kaleidoscope", covers a range of issues: storytelling, capitalism, technology, the politics of consumption, history after progress (a very interesting read), and ethics at the End of the World. All of this is provocative and suitably disturbing. Finally, section IV discusses the concept of the Anthropic Principle. I will try to paint the context Wallace-Wells presents: how fragile our civilization and ecosystems are, and how inevitable, drastic and long-term climate change will be.

Wallace-Wells lists several major misconceptions that we hold about climate change, "myths" that encourage us to be blasé about the end of the world envisioned by so many climate scientists. First, he says we believe the "fairy tale" that climate change is slow. It isn't. By geological or even human timescales, it is advancing at terrifying speed. Check your news stories of 2019; climate change is here. Second, many see climate change as a problem largely confined to the Arctic. Climate change is global of course. In 2019, Karachi recorded the hottest April of any city on earth ever, and in 2019 earth itself experienced the hottest June ever recorded. Third, many see climate change as a problem for the natural world and some species, like Polar Bears, but not for humanity. This misapprehension arises from our failure to see ourselves as part of nature, and a disruptive yet wholly dependent part at that. Fourth, many see climate change as a matter of slowly rising sea levels relevant only to low-lying coastal areas and remote tropical atolls. A fifth pernicious myth is that burning fossil fuels is a necessary price we pay to foster "economic growth and good paying jobs". These necessary benefits pay for themselves by creating the technologies needed to repair the problems caused by the resultant climate change, using, for example, carbon capture, cold fusion, daring experiments spraying other gases into the atmosphere or lead powder into the oceans, or building giant reflective umbrellas. In other words, more of the same hubris that got us here. Throughout the book Wallace-Wells drops 'fact bombs' that support my view that we are insane. Example, bitcoin (p. 33) consumes more electricity than is produced by all the solar panels on our planet. The same bitcoin produces as much CO_2 annually as one million transatlantic flights (p. 179), and nearly 2% of the global total CO_2 emissions.

We deeply embrace the belief that progress is built into our civilization and society. There will be more and better food, time-saving devices, medical life extending treatments, poverty eliminated, and endless entertainment and travel opportunities. This myth is readily embraced by the wealthy fractions of society and the well-off eagerly endorse claims, such as those of the biologist and prolific writer Steven Pinker (Pinker 2018), that every measure shows human progress, that wealth, the economy, longevity, health, human rights, etc., are improving and that the Cassandras have been repeatedly proven wrong. Malthus, Ehrlich, the Club of Rome, even David Attenborough can hang their heads in shame for doubting the sharp upward thrust of history. We tend to forget that for 95% of human history progress was, to say the least, minimal, that population growth was almost invisible (see Hardin 1995), and economic growth was not a concept, much less a reality. Only in the last 5% of our time on earth have we seen notable changes from the 200 000 years of hunter gatherers and even that period of "progress" has regularly been blighted by setbacks from wars, diseases, and various genocides and pogroms. So-called progress has been largely over the past 200 years a product of the massive consumption of fossil fuels. A major result has been the staggering increase to eight billion large, warm blooded, consumptive apes. A large portion still wallows in poverty and can't afford to attend a Raptor's game much less a holiday in space.

The glorious irony of climate change is, of course, that we are entirely to blame and that the fabulous wealth and sumptuous lifestyles we have created are the exact reasons we are careening to calamity. Several times Wallace-Wells highlights this important point. For example, on p. 53, "The graphs that show so much recent progress in the developing world (i.e., decline in poverty and hunger, improvement in life expectancy, education gender relations, and more) are, practically speaking, the same graphs that trace the dramatic rise in carbon emissions that has brought the planet to the brink of overall catastrophe". Everyone reading this review was/is/will be a major creative participant in climate change.

Climate change is occurring now, will accelerate in the future, will endure for thousands of millennia, and is entirely a product of the very recent past. Our impact on climate will last not until our grandchildren die off but for millions of years. We need more books like this one to slap us hard, to not sugarcoat reality with false reassurances. If we continue our current insanity, then our civilization will be a tiny blip of an afterthought in the eternity of climate change.

"Man is not clever enough to limit his greed to courses that will not destroy the ecosystem." —Gregory Bateson, *Mind and Nature* (E.P. Dutton, 1968)

Note: I have deliberately omitted the myriad terrifying scenarios recounted by Wallace-Wells. Read

the book. Meanwhile, I include Corn and Yalkin (2019), an examination of the great physical and mental toll on those scientists conducting research on climate change.

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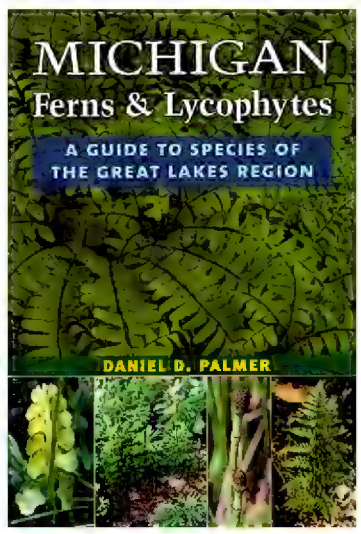
RON BROOKS

University of Guelph, ON, Canada

BOTANY

Michigan Ferns & Lycophytes: A Guide to Species of the Great Lakes Region

By D.D. Palmer. 2018. University Michigan Press. 381 pages, 29.95 USD, Paper.



The state of Michigan, USA, enjoys exceptionally rich floristic coverage and is admirably served both by the *Field Manual of Michigan Flora* by E.G. Voss and A.A. Reznicek (University of Michigan Press, 2012) and the excellent Michigan Flora Online (https://michiganflora.net/home.aspx). The *Field Manual* is widely seen to serve more than 'just' a local state flora function and to also provide a regional (Great Lakes) perspective. For decades, however, a curious gap in the state coverage has been with pteridophytes. Although a fern treatment was provided earlier by C. Billington's *Ferns of Michigan* (Cranbrook Institute of Science, 1952), and the University of Michigan was home base for American fern guru W.H. (Herb) Wagner for much of the time thereafter, no modern fern treatment existed. The current volume corrects that omission.

The book begins with a variety of standard introductory elements for a flora, including a brief summary of fern investigations in the state, a discussion of what makes pteridophytes 'tick', and a review of the abundance and distribution (including habitats) of pteridophytes in the state. A map showing the landscape diversity and/or major vegetation zones of Michigan would have been helpful here for understanding local distributions, especially for out-of-state readers, but the text does satisfy our basic needs in that regard. Similarly, it would have been useful to have a brief discussion of what makes Michigan's fern flora special on a regional or even continental scale. We eventually get some of this with discussion of endemics, but there are several broad biogeographic and evolutionary themes well represented in the Michigan pteridophyte flora that also could have been profitably discussed here.

It is quickly evident that *Michigan Ferns & Lycophytes* provides an admirable introduction and review of the distribution and identification of pteridophytes in that state. There are excellent photographic and line drawing illustrations of key identification features, only slightly hampered by the absence of scale bars. The *Isoetes* photo montage (p. 290), for example, is particularly effective for this tricky group. Individual treatments provide effective, clearly expressed technical descriptions for the taxon in question with an emphasis on identification. The comparative feature tables provided for most complex groups such as *Botrychium*, *Dryopteris*, *Equisetum*, *Lycopodiella*, and *Woodsia*, are very helpful. The identification keys for each genus are sound and are not overly laden with technical jargon. Distributional information seems to be quite up-to-date and accurate, although the unreferenced report of *Cystopteris tennesseensis* being (disjunct) in northern Ontario (p. 101) is news to us.

In some cases, we suspect treatments may be over-simplified. For challenging members of Lycopodiaceae, for example, it would be great to believe Great Lakes taxa are as straightforward to identify as they are presented to be in *Michigan Ferns & Lycophytes*. More than 30 years of wrestling with them on this side of the border suggests they are often otherwise!

Michigan Ferns & Lycophytes prominently claims a secondary objective, professing to share the same regional scope as that of the *Field Manual of Michigan Flora*. Yes, most Great Lakes pteridophyte taxa are found in Michigan, but that is equally true for New York, Ontario, Ohio, etc. To truly be a regional guide, however, also requires that a local treatment explicitly reflect the regional context. *Michigan Ferns & Lycophytes* falls short in this, particularly regarding

Canadian input. At least seven species are listed (pp. 11 and 238) as occurring in the Great Lakes portion of adjacent Ontario, Minnesota, and Wisconsin but not in Michigan, without further discussion. Another species—*Isoetes tuckermanii* A. Braun—and at least seven more hybrids known in Ontario from within this region are not even mentioned.

The discussion of *Dryopteris* hybridization (pp. 150–153) omits reference to any of the regionally—indeed, globally—significant cytological research on this genus undertaken by Ontario's Donald M. Britton. Similarly, the discussion of *Botrychium* (*s. l.*) diversity also makes no mention of how sites along the Ontario shore of Lake Superior were critical to the taxonomic discoveries and innovations of the University of Michigan team studying this group.

Simply put, Wagner and Britton made the largest contributions of anyone to our understanding of the pteridophytes of the Great Lakes. Accordingly, the absence of even a single citation from Britton's voluminous Great Lakes-relevant literature—not even W.J. Cody and D.M. Britton's 1989 *Ferns and Fern Allies of Canada* (Agriculture Canada)—is surprising, even within just a Michigan ferns context. Together, these various omissions present a significant credibility problem for *Michigan Ferns & Lycophytes*' claim to offer a regional perspective on Great Lakes pteridophytes.

There are 108 species treated in *Michigan Ferns & Lycophytes* (121 full treatments including a selection of some additional subspecies, varieties, or hybrids). Taxa within some genera are treated in considerable detail while others receive more basic consideration. The *Equisetum* treatment, for example, employs 42 pages of text for the treatment of 13 taxa. This includes species-comparable treatments for four sterile hybrids because they are "quite common and often form large clones" (p. 51). The considerably more ecologically, genetically, and biogeographically significant *Dryopteris* genus, however, is addressed in only 27 pages treating 12 taxa. This treatment includes stand-alone discussions of the two hybrids considered to be most common in the state. Another 16 hybrid combinations are listed as occurring in Michigan but without any supporting documentation or references. Why stop there? Readers should at least have been directed to some pertinent references from Britton's Ontario literature on *Dryopteris* hybrids and/or to James Montgomery's excellent 1982 North American treatment (Fiddlehead Forum 9: 23–30). The paucity of supporting references is a problem throughout, in fact, with the References section of the book having a surprisingly low total of fewer than 50 citations.

Etymology is discussed for each taxon that receives a stand-alone treatment. There is no harm in that because the origin of names has some popular interest. When these cultural/biographical discussions use large amounts of text space that could otherwise be profitably applied to the core identification objective of the book, however, they become counter-productive. The excessively long, biography-like etymological discussion for *Huperzia* ×*josephbeitelii* A. Haines (p. 318), for example, is twice the length of the remaining text available for the technical description of this difficult taxon.

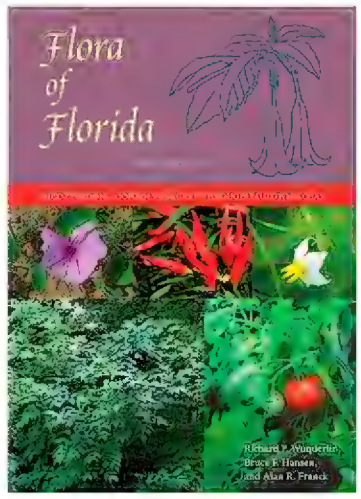
At its core, *Michigan Ferns & Lycophytes* presents a valuable tool for the identification of pteridophytes in Michigan and substantially fills a long-standing need. It also is an asset for the understanding of pteridophyte diversity in a geographically wider area as well. Out-of-state (especially Canadian) readers, however, will need a range of supplementary literature in order to gain the appropriate regional perspective.

DANIEL F. BRUNTON
Ottawa, ON, Canada

MICHAEL J. OLDHAM
Peterborough, ON, Canada

Flora of Florida Volume 6 (Dicotyledons, Convolvulaceae through Paulowniaceae)

By R.P. Wunderlin, B.F. Hansen, and A.R. Franck. 2019. University Press of Florida. 372 pages, 70.00 USD, Cloth.



The monumental *Flora of Florida* project is now over half completed. With the publication in 2000 of Volume 1 and a flurry of additional publication activity in recent years (for reviews of earlier *Flora of Florida* volumes see *The Canadian Field-Naturalist* 130: 248–249, 2016 [Volumes 2 and 3]; 131: 375, 2017 [Volume 4]; and 132: 68, 2018 [Volume 5]), there is but one more volume necessary to achieve complete coverage of the dicot taxa. The final three volumes treating the monocot species are then to be published. The authors' goal of having all 10 volumes in print by 2020 may not be achieved; putting out four volumes in less than a year and a half seems unlikely from both a production and marketing perspective. The good news, however, is that their ambitious completion objective may not be far off the mark.

A total of 470 species in 19 vascular plant families are treated here. That number of taxa addressed is increased by the description of additional subspecies, varieties, and/or named hybrids within particular species accounts. With the completion of Volume 6 some 2375 species have been described. All told, 62% of the 3834 species identified in Volume 1 as occurring or to have once occurred outside of cultivation in the state, have now been described. The names of a substantial number of excluded species that were reported in error or unconfirmed are also enumerated.

As within those parts of *Flora of Florida* that preceded Volume 6, effective species identification keys updated from Wunderlin's *Guide to the Vascular Plants of Florida* (University of Florida Press, 1998) are placed immediately after each genus description. Alphabetically arranged species treatments follow, each employing up-to-date nomenclature and commencing with the detailed and comprehensive compilation of synonyms that is a trademark of *Flora of Florida*. No compilation in the present volume, however, approaches the astonishing 75 synonyms listed in Volume 3 (pp. 220–223) for *Crataegus michauxii* Persoon!

The physical characteristics of each taxon are described in the text (and keys) with precise but not overly technical terminology. The text is presented in a small but easily readable type on good quality paper within a hard cover binding. That readability is particularly important because the text is un-illustrated. This is understandable in an already voluminous text but is nonetheless unfortunate, particularly for non-local readers who are likely less familiar with the Florida flora. Readers are encouraged to consult the online *Atlas of Florida Plants* (http://florida.plantatlas.usf.edu) for photos of most taxa, however, and for more detailed range information than is in the brief statements provided here.

Habitat and (especially) other life history considerations are described sparsely, this presumably also a reflection of space limitations and cost control. That is also unfortunate for readers 'from away' who could benefit from comparing ecological characteristics of Floridian plants with those of their own local populations. As with the other treatments Volume 6 addresses many species that extend northward into southern Canada. That range limit seems to be quite accurately reflected for the most part.

The copy examined for this review was weakly bound, the spine panel separating from the side boards after minimal use. This is contrary to my experience with the firmly bound copies examined for reviews of earlier volumes, however, and likely represents an infrequent aberration.

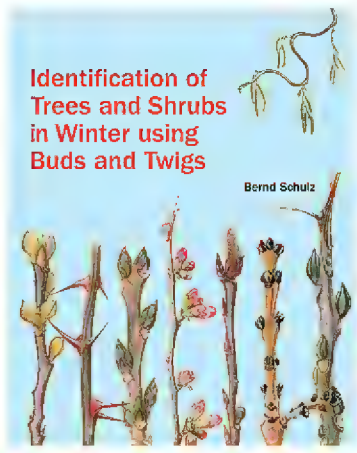
A considerable number of taxa in Volume 6 are in families such as Convolvulaceae, Solanaceae, and (especially) Acanthaceae which typically do not contribute substantially to floristic diversity in northern areas of this continent. Some families with more prominent northern diversity are well represented however, including Plantaginaceae, Lamiaceae, and Lentibulariaceae. Floridian representation of the insectivorous genus of bladderworts (*Utricularia*, Lentibulariaceae) for instance, includes four species which occur in eastern Canada. The description of Floridian populations of taxa such as the Eastern Purple Bladderwort (*U. purpurea* Walter) suggest striking differences may exist with the Canadian populations of this species—and perhaps with others as well.

The *Flora of Florida* is a grand undertaking that is providing a valuable floristic tool applicable far beyond the limits of that state. Were Volume 6 a standalone analysis, however, I would not recommend it as a high priority acquisition for northern botanists because of its lesser representation of north-related taxa than seen in earlier contributions. Just the same, however, it warrants serious consideration for northern libraries as a significant component of what will undoubtedly be a classic of North American botanical literature almost immediately upon its completion.

DANIEL F. BRUNTON
Ottawa, ON, Canada

Identification of Trees and Shrubs in Winter using Buds and Twigs

By Bernd Schulz. 2018. Royal Botanic Gardens, Kew, distributed by University of Chicago Press. 368 pages, 45.00 GBP, 80.00 USD, Cloth or E-book. Originally published in German as: Gehölzbestimmung im Winter: mit Knospen und Zweigen, 2013.



As a Canadian naturalist, how will you be spending the upcoming winter? Perhaps a Christmas Bird Count shortly after the landscape transforms into snow and ice, and then as frigid weather lingers toward a seemingly relentless polar vortex, maybe an occasional excursion such as hiking the trails in snowshoes and perhaps a nocturnal Mudpuppy hunt by the local dam? Many nature lovers by then become relatively dormant, and begin to dream about early spring arrival of migrating birds or of Skunk Cabbage bursting through a melting snowpack, only a month or two away.

How about hunting for trees and shrubs? Woody plants are always available for study, and are perhaps best observed during the winter months when distinctive twig features are fully developed and easily visible without being obscured by deciduous leaves (in contrast to herbaceous plants which may be withered and hidden under snow; e.g., Levine 1995). Besides being a rewarding and easily accessible winter activity from cultivated yards to remote wilderness, real contemporary conservation questions are awaiting resolution such as occurrences of populations for rare/threatened species: relevant examples from this writer's current work are establishing the locations of Red Spruce populations in the greenbelt of Ottawa, and documenting the presence of new Rock Elm populations in Quebec along the land border of eastern Ontario and Quebec (Vaudreuil-Soulanges; FloraQuebeca 2009). Spotting trees and shrubs is frequently best done in winter, coincidentally when there may be little else obvious for the naturalist to do outdoors. But how does one confirm that plant species of interest have really been found?

The 'fingerprint' of woody plant species identification is their twigs. All features of woody plants, from growth form to bark, leaves, flowers, and fruit, are useful to observe, but the only identification trait reliably present and virtually invariant among individual plants of a given species, at any age from sapling to centuries-old giant, is the twigs. Trees and shrubs can nearly always be accurately determined to genus via mature twig features (leaf scars, buds, etc.), and usually to species with a trained eye.

Bernd Schulz's *Identification of Trees and Shrubs in Winter using Buds and Twigs* is an excellent resource to learn the key features for differentiating woody plants from family to genus to species. The book is at its essence a thoroughly modern textbook sorely needed for a curriculum which, one may state with little exaggeration, is no longer actively taught. The book has useful and accessible chapters regarding the history of twig-identification botany, twig structure and terminology, and identification keys, but is at its core a comprehensive species-by-species treatment of the trees and shrubs found in central Europe with detailed descriptions and hundreds of technically sound and attractive colour illustrations. A number of high-quality twig identification books relevant to eastern North America were published from early to mid 20th century (e.g., Blakeslee and Jarvis 1911; Trelease 1918; Harlow 1941; Graves 1952; Core and Ammons 1958; Petrides 1958; Symonds 1958, 1963). These classic books are still very much useful and worth studying but suffer from being stuck in an historical era before the current "globalization" of cultivated plants, and the corresponding emergence of widespread naturalization and invasive species as dominant ecological features. Little on the subject was published from the 1960s until the 2010s. Schulz's book is therefore a major step forward toward modernization for the subject, with comprehensive descriptions and illustrations showing the native, cultivated, and naturalized plants of central Europe in the 21st century; there is much species overlap with the woody plants of eastern North America in modern times. The classic 20th-century books, in contrast, often give at most a light treatment of non-native plants, some of which have only arrived and become dominant in the wild in the last few decades.

It is worth noting that the subject matter of Schulz's book is not just relevant to winter: "winter" twig features (mature buds, etc.) are indeed present from late summer until spring, approximately two thirds of the year from August to April.

Despite being an authoritative and high-quality publication, a few features are worth considering which may be drawbacks to some of the intended audience. The book is large and heavy, with a typical 'textbook form' factor and so is not a portable handbook to be easily tossed in one's backpack. The book was written from a central European perspective, and so is a comprehensive treatment of the native, naturalized, and commonly cultivated trees

and shrubs of that region specifically. While there is much overlap of naturalized and commonly cultivated woody plants of Europe and North America, as noted above, some woody plants of Canada are not included. Evergreen trees and shrubs are not treated, so one cannot use this book to learn their identification traits: e.g., spruces versus firs or Sheep-laurel versus Bog-laurel. This book only considers twigs, and despite doing this with unprecedented breadth and depth, does not treat other aspects of woody plants such as growth form, leaves, etc. which many of the classic books cover in addition to twigs.

Overall, Schulz's book is highly recommended to anyone interested in temperate zone woody plants and their conservation, and is available at reasonable prices (~50.00–70.00 CAD) from a variety of sellers.

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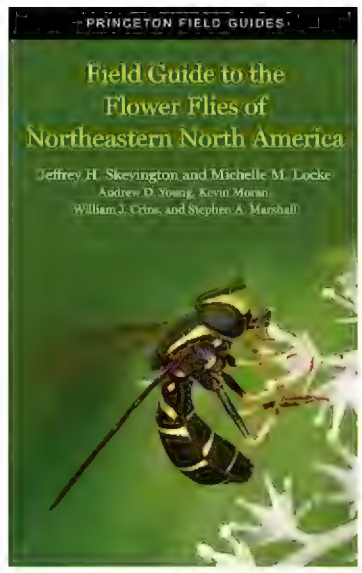
OWEN CLARKIN

Ottawa, ON, Canada

ENTOMOLOGY

Field Guide to the Flower Flies of Northeastern North America

By Jeffrey H. Skevington, Michelle M. Locke, Andrew D. Young, Kevin Moran, William J. Crins, and Stephen A. Marshall. 2019. Princeton University Press. 512 pages, 3000 images, and 414 maps, 27.95 USD, Flexibound Paper.


PRINCETON FIELD GUIDES
Field Guide to the Flower Flies of Northeastern North America
Jeffrey H. Skevington and Michelle M. Locke
Andrew D. Young, Kevin Moran
William J. Crins, and Stephen A. Marshall

This is a beautiful book, big enough to include multiple photographs of all the known, and until recently, a few unknown flower flies, yet small enough to be carried into the field in a largish pocket or small satchel.

The general introduction describes the book's layout and how to use it most efficiently. Techniques on observing and trapping these flies and how to record your data are also included. Identification pointers, including a reference to an online Key to the Genera of Nearctic Syrphidae (Miranda *et al.* 2013), give the reader a good start to determining the species. The book ends with a thorough glossary and several very useful diagrams illustrating much used anatomy.

Prior to the species accounts is a two-page spread illustrating the differences among the four subfamilies of flower flies. Having never attempted to key out one of these flies to species before, I used this two-page spread, largely with success. One then goes to the colour-coded section of the book for the appropriate subfamily to find their insect. And herein lies the one issue I have with this guide. Because there is no further key to identify the species, the reader may have to flip through quite a number of pages before finding their fly. The online Key to the Genera of Nearctic Syrphidae, co-authored by four of the six authors of this book as well as two others, should be downloaded and used in conjunction with the guide to identify your specimen to species.

The species accounts are well done. There are two per double-page spread, with text on the left and images on the right, allowing for rapid flipping while you're trying to find your fly. There is always a dorsal view and lateral view, sometimes more than one if the species is dimorphic. Other salient features, such as wing venation, facial structure, or leg characteristics are also shown, as needed, and nicely magnified. All the photographs are at least adequate, but most are crisp, often beautiful shots.

The text includes a size range, but the silhouette of the fly presented with each species gives a more rapid indication of size. An interesting series of icons that I've not seen before tells the reader if the insect can typically be identified by the unaided eye (surprisingly many), a hand lens or, ultimately, if a microscope will be needed. A map showing records, and usually a range estimate as well, does not restrict itself to the geographic scope of this book, but includes all of North America. The text includes flight times, abundance, and identification tips; I couldn't think of anything else that a field guide should have.

Overall, this is a very nice book that, in conjunction with the online key, will do its job quite well.

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Miranda, G.F.G., A.D. Young, M.M. Locke, S.A. Marshall, J.H. Skevington, and F.C. Thompson. 2013. Key to the Genera of Nearctic Syrphidae. Canadian Journal of Arthropod Identification 23: 23 August 2013. https://doi.org/10.3752/cjai.2013.23

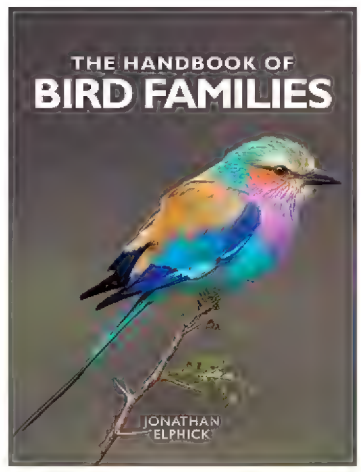
RANDY LAUFF

Department of Biology, St. Francis Xavier University, Antigonish, NS, Canada

ORNITHOLOGY

The Handbook of Bird Families

By Jonathan Elphick. 2018. Firefly Books and The Trustees of the Natural History Museum, London. 416 pages, 35.00 CAD, Paper.



As most people with more than a slight interest in birds understand, the taxonomy of Aves is at present in flux. Much of the changing taxonomic attribution is a consequence of molecular DNA research. The best thing that may be said about this book is that, published in 2018, it has the most up-to-date presentation of what is understood about avian taxonomic relationships outside of scientific journals. The first thing one notices by thumbing through the book is that it is rather dense with very little white space and a small font. It would seem that reducing publication cost has driven the layout and presentation.

In the two-page introduction, Elphick briefly explains the scientific classification system. In defining families, he follows the arrangement of the fourth edition of *The Howard and Moore Complete Checklist of the Birds of the World* (Aves Press, 2013/2014) and notes that this is a conservative approach. He indicates here there are 36 orders and 234 families of birds by latest account.

The Table of Contents under the heading "The Bird Families" lists 36 orders but, curiously, lists no families. The main text offers a brief explanation of each order followed by the families in that order. Each family is then given a box in which the same basic information is covered, such as: social behaviour, nest, food, voice, and migration. Because the information, in some cases, may cover dozens of genera and hundreds of species I did not find it particularly useful. In fact, the author is often reduced to stating that species vary hugely in these regards.

Under the heading "Conservation Status" he lists the names of those species that are at the highest categories of threat and then, for the less threatened categories, just the number of species in each. There is an appendix in which the definitions of the Birdlife/IUCN Red List categories are presented, but I wish the author, who stated his goal to make this book an accessible presentation, had paraphrased the definitions which, in their original form, are anything but easy to understand.

Following the "quick box" the author provides accounts that vary in length usually depending on the size of the family. The most relevant informative parts of these accounts are the explanations of taxonomic relationships within the family and comparisons to other closely related families. In the past few years, many species have been moved from one family to another, or in some cases to a brand-new family. Many of the new groupings based as they are on DNA evidence will seem counter-intuitive to birders. The author explains that convergent evolution may produce similar appearing birds that are in quite different families.

Within these accounts are numerous interesting factoids that the author has gleaned from his own studies and from the literature. However, as this book is an attempt to provide an easy-to-understand presentation of the classification of bird families, I would have preferred that it stuck to those aspects and left behavioural anecdotes to other books.

So, sticking to taxonomy, the world birder will be fascinated in some cases and perplexed in others about the arrangement and composition of families. Here are a few examples in no particular order that astonished me:

- The rail-babbler of southeast Asia is no longer a monotypic family but is now in the family Eupetidae along with the two rockfowl of West Africa and the two rockjumpers of southern Africa.
- The Wrenthrush and the two Cuban *Teretistris* warblers are lumped into the family Zeledonidae.
- The once huge family Sylviidae or "Old World Warblers" continues to be disassembled and, at present, contains 62 species and is "often referred to as the sylviid babblers" (p. 359). In fact, there are only five species in the once large genus, *Sylvia*. If you hear reference to Juniper Babbler note that it is what you knew as the Abyssinian Catbird (personally I find any taxon with the appellation Abyssinian to be exotic beyond words). It is difficult to believe that the distinctive Asian parrotbills will not soon again be split off from the other sylviids.
- Bird family seekers who made the trek to Kuwait to tick the Hypocolius family may be dismayed to find that Hylocitrea of far-off Sulawesi (one or two species depending on your authority) has been added to the family. It may not remain this way.

To harp on the author's goal of producing an accessible account of families, his decision to not include a representative photograph of each family is a major flaw. Better to dispense with word descriptions and include an image for each family and a photo of distinctively different species within a family such as rockjumper and rail-babbler. I counted at least 11 families with no photo and other highly distinctive and well-known groups within families that would have greatly benefitted from a photo.

The photos are generally good. Picture credits are listed at the end in a tiny print format. I much prefer the photographer to be noted in the caption; this could have been done by reducing the banal captions.

I found numerous errors that might have been detected by better editing. Here are a few examples:

- On p. 160 the order Piciformes is said to comprise four families but then (correctly) five are listed.
- On p. 173 the monotypic Cuckoo Roller is listed as being in one of the families in the order Coraciiformes, whereas earlier on p. 149 it is assigned a unique order, Leptosomiiformes, the latter acknowledged to be the correct positioning.
- Two species of Crescentchests (Melanopareiidae) are described to "inhabit very large areas in east central and central *North* America" (p. 220, italics mine).
- Within the account on Antpittas (Grallaridae) on p. 222, "ant-thrushes are in the new Family Grallariidae". Replace "ant-thrushes" with "antpittas" for this sentence to make any sense.
- On p. 349 the exact same sentence is used twice within the same paragraph to describe the appearance of Cupwings (Pnoepygidae), an error that could easily be picked up by editing.
- On p. 362 Elphick refers to "the renowned British nineteenth century ornithologist" but does not name him.
- On p. 368 the Palmchat (Dulidae) is described as one of only two families endemic to the Caribbean, the other being Todidae, thus forgetting the Warbler Tanagers (Phaenicophiliidae) described on pp. 317–318, all nine species of which are found only in the Caribbean.

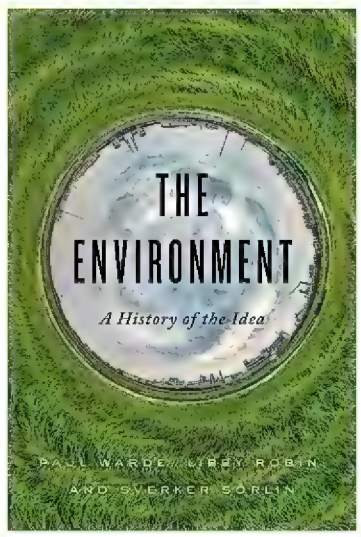
In summary, this book provides a 2018 snapshot of ornithological thinking about world bird families. Unfortunately, in this reviewer's opinion the work cut too many corners perhaps based on space and time restrictions. At 35.00 CAD it is likely worth the cost but the *Bird Families of the World* (Lynx Edicions, 2015), while slightly older and thus not as up-to-date as the present volume, would still be a better purchase at 87 Euros for most birders seriously interested in bird families.

BOB CURRY
Burlington, ON, Canada

OTHER

The Environment: A History of the Idea

By Paul Warde, Libby Robin, and Sverker Sörlin. 2018. Johns Hopkins University Press. 256 pages, 29.95 USD, Cloth.



Did you know that although the word "environment" has been used in the English language for over 200 years, our present concept of "the environment" only began to take shape about 70 years ago? In *The Environment: A History of the Idea*, authors Paul Warde, Libby Robin, and Sverker Sörlin have put together a fascinating work coalescing the history of our modern concept of the environment. Consisting of a brief prologue, seven chapters, and appended with a detailed notes section, brief bibliographic essay, and index, this book consists of an intellectual history of the relatively recent (post-World War II) environmental concept.

Each of the book's seven chapters illustrates the historical development of various key components of our modern concept of "the environment". Chapter 1 introduces foundational works from the early postwar era that contributed to the modern environmental concept, such as William Vogt's (1948) *Road to Survival* (paid homage by the chapter name and mentioned/discussed numerous times within the book). Additionally, the first chapter sets forth the authors' proposed "Four Dimensions of 'Environment'" (p. 14) consisting of expertise, the future, trust in numbers, and scale/scalability. Chapters 2–7 summarize a variety of evolving concepts and scientific developments, such as computer modelling, post-world war resource conservation concerns, the birth of ecology, climate change, non-governmental organizations, international politics, the concept of the Anthropocene, and the newly emerging field of environmental humanities (to list but a few examples!). Additionally, these chapters detail the major and rapid evolution of the modern concept of the environment, particularly illustrated via summaries of the subjects of environmentally-focussed conferences occurring after 1948.

Each chapter is relatively concise (approximately 25 pages in length) and provides a history of important, interrelated components crucial to the shaping of modern environmental thinking. Although each chapter is largely its own piece, I found some portions of each to overlap at times in terms of content, often referring to other chapters within the book. This does not detract from the work as a whole, however, but illustrates how a number of distinct but interweaving concepts coalesce to form the modern concept of the environment. I found this book to largely avoid technical language, with references and technical notes appended into a considerable Notes section at the end of the book. This makes the book more accessible to the non-specialized reader but allows one to dive further into the material referenced if desired. While each chapter is a summary of historical context, the authors add to its value and interpretation by providing meaningful original commentary and analysis throughout the book.

Should you give it a read? Absolutely. Do not let the "history" in the title dissuade you from giving this book a try if you are not a history buff: this book is intended for a broad audience. The authors have followed their own suggestion by writing this work as a means of "framing a problem or concept as a narrative or story" (p. 178). I felt like much of the writing is presented in almost a 'story-like' narrative. In some parts, I almost felt as if I were listening to the authors discuss the content of the book over coffee. Overall, I found *The Environment: A History of the Idea* to be an accessible, enjoyable, and very informative read: I learned something new at the turn of nearly every page. Also, this work contains many references to other books (in addition to so much more) and as a result has introduced me to a number of titles which are now on my future reading list. I highly recommend *The Environment: A History of the Idea* to anyone with an interest in any aspect of environmental study. This would likely include most readers of *The Canadian Field-Naturalist*.

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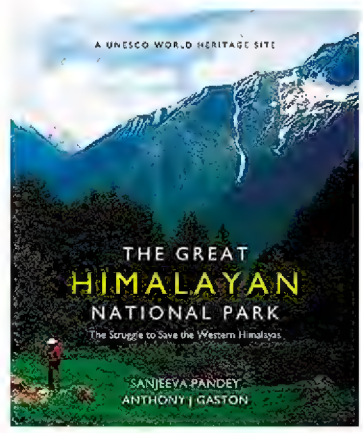
SEAN M. HARTZELL

Bloomsburg University of Pennsylvania,
Bloomsburg, PA, USA

The Great Himalayan National Park: The Struggle to Save the Western Himalayas

By Sanjeeva Pandey and Anthony J. Gaston. 2019. Niyogi Books. 364 pages, 284 colour photos, and 15 maps, 54.00 CAD, Cloth.



The Himalayas: surely this is one of the most evocative names in world geography, for who has not seen inspiring images of the world's grandest peaks and heard epic tales of scaling their summits? This book is set in the Himalayas but to appreciate its significance you must lower your eyes a few degrees, focussing not on the snow-shrouded crags but on the green slopes below, on the meadows and forests. The biological richness of the Himalayas lies at these elevations, not in the awe-inspiring realm of rock, ice, and snow. The mountains' richness rests on three axes: first and most conspicuously, a vertical dimension, driven by the steep climate gradient tied to elevation that generates profoundly different habitats for a diverse suite of species. Secondly, there is a sharp north-south axis because the height of the Himalayan range makes it a barrier between two major biogeographic realms. Thus, you can have Himalayan Brown Bears (*Ursus arctos isabellinus*) and Ibex (*Capra sibirica sakeen*) of the Palearctic realm living just over the ridge from Asiatic Black Bears (*Ursus tibetanus*) and Himalayan Serow (*Capricornis thar*) of the Oriental realm. Finally, there is an important west to east increase in rainfall. All three of these considerations make the area selected for the Great Himalayan National Park a geographic crossroads meriting special protection, especially given the threat of fragmenting ecological continuity. Imagine a species inhabiting forests on the south face of the Himalayas at elevations between 2000–3000 m; their geographic range is essentially a long narrow ribbon, easily severed by deforestation. Indeed, throughout the Himalayas forests at these intermediate elevations are markedly underrepresented in protected area systems. These perspectives are introduced in the book's opening chapter and prominent throughout, along with the other main rationale for siting a park here: the area's low levels of human settlement and concomitant disturbance from logging and livestock grazing.

The next chapter, "Trekking", describes in lovely prose and photos what a visit to the park is like and it has inspired me to try to organize a return. (Full disclosure: I participated in two of the early surveys [spring and fall of 1980] organized by Tony Gaston that became a foundation for park creation but have not been back since.) Unfortunately, as a 'details person' I found it frustrating not to be able to find most of the spots described or photographed on the maps; even the trekking routes are not mapped.

In "Development of GHNP", the book returns to the 1980s and the creation of the park. Some of this chapter is down in the weeds of the requisite steps that are specific to India's governance but of wider interest is how park development was advanced with the local population. Thoughtful park design mitigated some potential conflicts, i.e., by delineating a core area that contained just three villages (120 inhabitants) and then along the western boundary creating a 230 km^2 Ecodevelopment Zone that held 160 villages with 14 000 people. Traditional rights to collect herbs for personal use became a problem when this morphed into commercial sales on which a thousand households were dependent, and inevitably these people became very agitated when this commerce was terminated. The key to recovery came in the formation of 95 Women's Saving and Credit Groups (a large number to accommodate both different villages and different social strata) that earned income from vermicomposting and other activities. Further insights into park-people relations are covered in "People and the GHNP", which has a potpourri of sections including religious traditions (sacred trees and groves), education (from 1989 to 2002 the only school in the park was in a cave), species targetted by herbalists, and the creation of a support organization, Friends of GHNP, with the Western Tragopan (*Tragopan melanocephalus*) as its mascot. The Friends group took the lead in applying for UNESCO World Heritage Site status for the park and adjoining protected areas, collectively an area of 2854 km^2, thus garnering formal recognition of the global significance of this place.

The next three chapters focus on the park's natural history, the first a seasonal chronicle beautifully illustrated with flower photos, followed by two overviews of the park's birds and mammals with special attention on charismatic species like the pheasants and carnivores. In the final chapter, "Future of Biodiversity in the Western Himalayas", the authors ruminate on the on-going process of managing the park in a way that will further the interests of the local people while maintaining its unique biological heritage. This challenge will unfold in the face of ever-changing threats, such as tourism pressures from the millions of Indians who seek cool, pleasant playgrounds to escape Delhi and other cities.

In summary, this book shares many attributes—such as wonderful photographs and writing—with other volumes that have been written to celebrate the natural wonders of the world's special places. It differs from most analogous books in the depth with which it tells the story of all the hard work that underlies protecting such places—from foundational science to pure politics. I particularly enjoyed the distillation of this that is captured nicely in the Foreword and Afterword, written by Gaston and Pandey respectively, in which they give personal accounts of the decades of work they have devoted to this unique place. All in all, it is a tale that should be of interest to anyone concerned with protected area creation and management, especially in places where the livelihoods of local people are directly and tightly tied to natural resources.

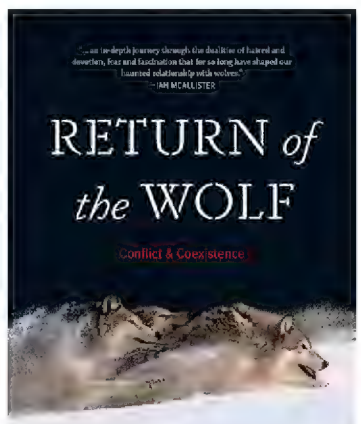
MALCOLM L. HUNTER, JR.

Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, Orono, ME, USA

ZOOLOGY

Return of the Wolf: Conflict and Coexistence

By Paula Wild. 2018. Douglas and McIntyre. 272 pages, 32.95 CAD, 29.95 USD, Cloth.



Return of the Wolf by Paula Wild was an easy, enjoyable read about the recovery and return of wolves (*Canis* spp.) throughout the world, focussing much of her time in her home country of Canada studying Gray Wolves (*Canis lupus*). The purpose of the book is to give the real picture of wolves, as neither saint nor sinner nor good versus bad, but rather just another animal (albeit a predator that often conflicts with humans where the two are sympatric) trying to survive in an increasingly human-dominated landscape. Wild provides an historical summary of wolves in both the Old World as well as the New World, given that they were once common throughout North America and Eurasia. Chapters 2 and 3 describe how bounties and organized hunts had drastically reduced their numbers worldwide by the 1900s. However, the wolf is now recovering from near extermination in many areas, especially parts of the United States' lower 48 states, and is becoming more common as evidenced by their recovery in the Yellowstone area (p. 149) and upper mid-west. Throughout the book, Wild expresses amazement at the dualities of hatred and love that she encountered when ascribing emotions about wolves in her mission to set the record straight by letting us appreciate the real animal. I have over 50 books on wolves—not even counting the 25+ I have on their close cousin the Coyote, *Canis latrans*—and I feel like this book is an appropriate summary of all those books. It provides much of the historical background of, say, Barry Lopez's 1978 *Of Wolves and Men* (Scribner, 2004), but also discusses modern happenings such as Yellowstone wolf recovery (see Way 2017) and marine-food-eating coastal wolves discussed in Ian McAllister's book *The Last Wild Wolves: Ghost of the Great Bear Rainforest* (University of California Press, 2007). Curiously, the title of Wild's book is strangely similar to two other books I own, including *The Return of the Wolf* (NorthWord Press, 1999) by Steve Grooms, which presents the wolf's comeback in Canada and the United States, albeit 25 years ago now, and *The Return of the Wolf: Reflections on the Future of Wolves in the Northeast* (University Press of New England, 2000), edited by John Elder, that discusses the implications and potential of wolves returning to the northeast United States.

Return of the Wolf is a mixture of natural history, native peoples' stories, and conversations with scientists and conservationists. We learn how society's attitudes affect the population dynamics, behaviour, and conservation of wolves on the modern landscape, a setting where more and more people appreciate having nature around even if it challenges us both financially and safety-wise. Wild notes that the fate of wolves remains uncertain and she questions how humans will adapt to wolves. She is optimistic that we will, noting that "I want to hear the wolves but I don't want them to come too close. For their safety, not mine" (p. 241). Accordingly, the first Appendix item is a unique 2.5 page "Wolf Safety Checklist" (p. 243–245), one that you might think is more in tune with living in bear country. However, Wild spends much of the second half of her book discussing 'the myth' that wolves are not dangerous and documents that healthy (i.e., not rabid) wolves are increasingly confronting, and sometimes even killing, humans in North America (Chapter 9). She also describes some first-hand accounts of highly habituated wolves living on Vancouver Island, British Columbia (Chapter 10). In fact, the ecology of those animals

living in human-dominated areas reminds me of the wolf's smaller cousin, Coyote (e.g., Way 2014), in many respects. Of course, it is important to keep in mind that even with increasing boldness of some wolves, the chance of one harming us is still astronomically small compared to potential dangers from our everyday activities.

Given my interest in studying Eastern Coyotes/coywolves (Way 2014), I was fascinated with Wild's discussion of this animal (pp. 91–96) and her decision—due to their unique genetic background—to call them coywolves. While describing the rapid evolution of the coywolf, Wild also discusses the other lesser known wolves, Eastern Wolf (*Canis lycaon*) and Red Wolf (*Canis rufus*), which are possibly the same species living on opposite ends of their native eastern North American range. Wild circles back to Eastern Wolf a few times when also discussing recent aggressive encounters people have had with wolves, some of those with Eastern Wolves in Algonquin Provincial Park.

Overall, this is an easy-to-read, well researched, timely book. While perhaps not having the exciting flair of a book written by a biologist(s) in their study area, it provides a great up-to-date account of the happenings of wolves worldwide, with a North American focus. Whether you are new to the world of wolves, or a veteran, I recommend adding this book to your library. The nice 16-page colour plate section as well as many black and white photos adds greatly to the read. Hopefully, it will provide food for thought and create compassion for a creature that has been maligned for far too long.

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JONATHAN (JON) WAY

Eastern Coyote/Coywolf Research, Osterville, MA, USA

NEW TITLES

Prepared by Barry Cottam

Please note: Only books marked † or * have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books—or copies for review—to the Book Review Editor.

†Available for review *Assigned

Currency Codes: CAD Canadian Dollars, AUD Australian Dollars, USD United States Dollars, EUR Euros, GBP British Pound.

BIOLOGY

Fires of Life: Endothermy in Birds and Mammals. By Barry Gordon Lovegrove. Foreword by Roger S. Seymour. 2019. Yale University Press. 384 pages, 40.00 USD, Cloth.

The Evolutionary Biology of Species. Oxford Series in Ecology and Evolution. By Timothy G. Barraclough. 2019. Oxford University Press. 288 pages, 90.00 USD, Cloth, 45.95 USD, Paper. Also available as an E-book.

The Tangled Tree: A Radical New History of Life. By David Quammen. 2018. Simon & Schuster. 30.00 USD, Cloth, 18.00 USD, Paper, 11.99 USD, E-book.

The Ethnobotany of Eden: Rethinking the Jungle Medicine Narrative. By Robert A. Voeks. 2018. University of Chicago Press. 328 pages, 45.00 USD, Cloth, 10.00–45.00 USD, E-book.

Evolution in the Dark: Darwin's Loss Without Selection. By Horst Wilkens and Ulrike Strecker. 2017. Springer International Publishing. 226 pages, 179.99 USD, Cloth or Paper, 139.00 USD, E-book.

BOTANY

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Freshwater Ecology and Conservation: Approaches and Techniques. Edited by Jocelyne Hughes. 2019. Oxford University Press. 464 pages, 90.00 USD, Cloth, 45.95 USD, Paper. Also available as an E-book.

Hierarchy: Perspectives for Ecological Complexity. By T.F.H. Allen and Thomas B. Starr. 2017. University of Chicago Press. 352 pages, 125.00 USD, Cloth, 47.50 USD, Paper, 10.00–47.50 USD, E-book.

Time in Ecology: A Theoretical Framework. By Eric Post. 2019. Princeton University Press. 248 pages, 105.00 USD, Cloth, 40.00 USD, Paper. Also available as an E-book.

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ENTOMOLOGY

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ICHTHYOLOGY

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Deep-Sea Fishes: Biology, Diversity, Ecology and Fisheries. By Imants G. Priede. 2017. Cambridge University Press. 492 pages 89.99 USD, Cloth.

ORNITHOLOGY

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ZOOLOGY

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†A Field Guide to Marine Life of the Outer Coasts of the Salish Sea and Beyond. By Rick M. Harbo. 2019. Harbour Publishing. 8-fold pamphlet, 7.95 CAD, Paper.

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Cats in Australia: Companion and Killer. By John Woinarski, Sarah Legge, and Chris Dickman. 2019. CSIRO Publishing. 344 pages, 59.99 AUS, Paper.

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OTHER

***To Speak for the Trees: My Life's Journey from Ancient Celtic Wisdom to a Healing Vision of the Forest**. By Diana Beresford-Kroeger. 2019. Random House Canada. 289 pages, 32.00 CAD, Paper.

Wild Sea: A History of the Southern Ocean. By Joy McCann. 2019. University of Chicago Press. 256 pages, 28.00 USD, Cloth, 18.00 USD, E-book.

Good Enough: The Tolerance for Mediocrity in Nature and Society. By Daniel S. Milo. 2019. Harvard UP. 320 pages, 28.95 USD, Cloth.

An Alfred Russel Wallace Companion. Edited by Charles H. Smith, James Costa, and David A. Collard. 2019. University of Chicago Press. 416 pages, 60.00 USD, Cloth or E-book.

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Wilding: Returning Nature to Our Farm. By Isabella Tree. Introduction by Eric Schlosser. 2019. Picador. 392 pages, 19.95 USD, Paper. Also available as an E-book.

Naturally Curious. A Photographic Field Guide and Month-By-Month Journey Through the Fields, Woods, and Marshes of New England. Second Edition. By Mary Holland. 2019. Trafalgar Square Books. 496 pages, 32.95 USD, Paper.

Wading Right In: Discovering the Nature of Wetlands. By Catherine Owen Koning and Sharon M. Ashworth. 2019. University of Chicago Press. 264 pages, 30.00 USD, Paper, 90.00 USD, Cloth, 10.00–35.00 USD, E-book.

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The Routledge Handbook of the Polar Regions. Routledge International Handbooks. Edited by Mark Nuttall, Torben R. Christensen, and Martin J. Siegert. 2018. Routledge, Taylor & Francis Group. 530 pages, 260.00 USD, Cloth. Also available as an E-book.

Everyday Creatures. A Naturalist on the Surprising Beauty of Ordinary Life in Wild Places. By G.J. Kenagy. 2018. Dockside Sailing Press. 220 pages, 15.95 USD, Paper, 203 pages, 5.99 USD, E-book.

For the Birds: American Ornithologist Margaret Morse Nice. By Marilyn Bailey Ogilvie. 2018. University of Oklahoma Press. 320 pages, 39.95 USD, Cloth, 34.95 USD, E-book.

Slime: How Algae Created Us, Plague Us, and Just Might Save Us. By Ruth Kassinger. 2019. Houghton Mifflin Harcourt. 320 pages, 26.00 USD, Cloth, 16.99 USD, Paper.

The Canadian Field-Naturalist

News and Comment

Upcoming Meetings and Workshops

Canadian Herpetological Society Annual Conference

The Canadian Herpetological Society Annual Conference to be held 20–23 September 2019 at the Redpath Museum in McGill University, Montreal, Quebec. Registration is currently open. More information is available at http://canadianherpetology.ca/conf/index.html#2019.

Wildlife Society and American Fisheries Society Joint Annual Conference

The first Wildlife Society and American Fisheries Society Joint Annual Conference to be held 29 September–3 October 2019 at the Reno-Sparks Convention Center, Reno, Nevada. Registration is currently open. More information is available at https://afstws2019.org/.

Student Conference on Conservation Science-New York

The 10th annual Student Conference on Conservation Science-New York to be held 2–4 October 2019 at the American Museum of Natural History, New York, New York. Registration is currently open. More information is available at https://www.amnh.org/research/center-for-biodiversity-conservation/convening-and-connecting/student-conference-on-conservation-science-new-york-sccs-ny.

Association of Field Ornithologists and the Wilson Ornithological Society Joint Meeting

The joint meeting of the Association of Field Ornithologists and the Wilson Ornithological Society, hosted by the New Jersey Audubon's Cape May Bird Observatory, to be held 27–30 October 2019 at the Grand Hotel, Cape May, New Jersey. Registration is currently open. More information is available at http://www.cvent.com/events/2019-afo-wos-joint-meeting/event-summary-fc644f2542184eba9fe3b-1d37928e0fd.aspx.

Entomological Society of Ontario

The annual general meeting of the Entomology Society of Ontario to be held 1–3 November 2019 at the Bark Lake Conference Centre, Haliburton, Ontario. More information is available at https://www.entsocont.ca/.

Entomology 2019

The annual meeting of the Entomological Society of America to be held 17–20 November 2019 at the America's Center Convention Complex, St. Louis, Missouri. Registration is currently open. More information is available at https://www.entsoc.org/events/annual-meeting.

James Fletcher Award for *The Canadian Field-Naturalist* Volume 132

The James Fletcher Award is awarded to the authors of the best paper published in a volume of *The Canadian Field-Naturalist* (CFN), and first started with Volume 130. The award is in honour of James Fletcher, founder of the Ottawa Field-Naturalists' Club (OFNC) and the first editor of CFN's earliest iteration, *Transactions of the Ottawa Field-Naturalists' Club*. A subcommittee of the OFNC Publications Committee sifted through all papers in Volume 132 of CFN, and came up with a list of the top five papers. From these top five, the committee selected the top paper, which for this volume was actually a tie between two papers, both of which receive the James Fletcher Award. The awards for Volume 132 of CFN go to:

Joseph J. Bowden, Kyle M. Knysh, Gergin A. Blagoev, Robb Bennett, Mark A. Arsenault, Caleb F. Harding, Robert W. Harding, and Rosemary Curley. The spiders of Prince Edward Island: experts and citizen scientists collaborate for faunistics. Canadian Field-Naturalist 132(4): 330–349. https://doi.org/10.22621/cfn.v132i4.2017

- This paper presents the first comprehensive list of spider species on Prince Edward Island, increasing the known list from 44 to 198 species, which is a huge accomplishment. The paper also used a unique collaboration between experts and citizen scientists.

And to:

Richard Troy McMullin, Katherine Drotos, David Ireland, and Hanna Dorval. Diversity and conservation status of lichens and allied fungi in the Greater Toronto Area: results from four years of the Ontario BioBlitz. Canadian Field-Naturalist 132(4): 394–406. https://doi.org/10.22621/cfn.v132i4.1997

- This paper presents data on a concentrated effort to collect observations of lichen species during the Ontario BioBlitz in the Greater Toronto Area over four years, and demonstrates the utility of rapid assessments for monitoring the diversity of lichens. This paper was based on a collaboration between experts and citizen scientists.

Congratulations to Joseph Bowden and co-authors and to Troy McMullin and co-authors for writing these excellent papers.

The runners up for this award are:

Chris R.J. Hay, R. Greg Thorn, and Clinton R. Jacobs. Taxonomic survey of Agaricomycetes (Fungi: Basidiomycota) in Ontario tallgrass prairies determined by fruiting body and soil rDNA sampling. Canadian Field-Naturalist 132(4): 407–424. https://doi.org/10.22621/cfn.v132i4.2027

- This paper used genetic techniques and traditional survey methods to describe the diversity of Agaricomycetes in Ontario tallgrass prairies.

Sue Carstairs, Marc Dupuis-Desormeaux, and Christina M. Davy. Revisiting the hypothesis of sex-biased turtle road mortality. Canadian Field-Naturalist 132(3): 289–295. https://doi.org/10.22621/cfn.v132i3.1908

- This paper tested a long-standing hypothesis that female turtles are more at risk of road mortality than males using a unique dataset collected at the Kawartha Turtle Trauma Centre, and found evidence to refute this hypothesis: both sexes were just as likely to be struck on roadways in three of four turtle species.

Rebekah Neufeld, Cary Hamel, and Chris Friesen. Manitoba's endangered alvars: an initial description of their extent and status. Canadian Field-Naturalist 132(3): 238–253. https://doi.org/10.22621/cfn.v132i3.1865

- This paper describes endangered alvars in Manitoba, describing their extent, plant communities, and land use.

Congratulations to these finalists. We would also like to show our appreciation to all authors who chose to share their interesting and valuable field-based studies with the readers of Volume 132 of *The Canadian Field-Naturalist*.

WILLIAM D. HALLIDAY AND JEFFERY M. SAARELA
OFNC Publications Committee

Diana Beresford-Kroeger: a new book, a life's work

Classical botanist, medical biochemist, and revolutionizer of how we look at forests has—by the time you read this—launched her seventh book. The event is scheduled for 24 September 2019 in Toronto, and we will have a review of it in our next issue of *The Canadian Field-Naturalist*. In the meantime, here is a brief note on Diana, the book, and selected aspects of her work. I spoke with her by telephone—she in Ottawa, I in rural Prince Edward Island—on 13 August 2019 and this account is based in part on our conversation.

The title of her new book, *To Speak for the Trees:*

My Life's Journey from Ancient Celtic Wisdom to a Healing Vision of the Forest (Penguin Random House, 2019), captures the essence of her work, which is a unique combination of almost-lost beliefs in the forest-enabled human connection with nature and the eruption of recent research into the wholeness of land, sky, and waters through the forests. The capacity to hold in the mind—and body and spirit—the knowledge of both modern science and indigenous systems built on that wholeness is rare. Fortunately for the planet, it is becoming less rare, and Diana's lifework is a major stream contributing to this 'new renaissance'. She's particularly encouraged by the range of engagement, from community efforts to improve the health of cities and neighbourhoods to the activism of youth world-wide to combat climate change. Diana informed me of the 2017 passing by the New Zealand Parliament of an Act that gives the Whanganui River the status and rights of a person, a precedent-setting major step forward that settled years of litigation and provided funding for improving the health of the river.

Diana's previous books celebrate and urge preservation of the world's forests, especially the boreal forest ringing the north, the last, relatively intact great forest on Earth. The message is simple: the forests are key to the survival of life on the planet, including human life. And it isn't just the capacity to survive but the quality of life in all its aspects. With their concept of "forest bathing", the Japanese have been aware of this for over 1000 years; through her writings—including a chapter in the forthcoming *International Handbook of Forest Therapy*—and other media, Diana is helping bring this practice to North America. Her research in biochemistry has enabled her both to understand the chemical communications among trees and the impact of that communication on land and waters and how that biochemistry can be harnessed for human health: mental, physical, and spiritual. She is also an accomplished medical researcher with some 300 articles to her name. Perhaps the most easily accessible summary of her work can be found in the inspiring documentary *Call of the Forest: The Forgotten Wisdom of Trees*, which can be viewed on the TVO website (https://www.tvo.org/video/documentaries/call-of-the-forest-the-forgotten-wisdom-of-trees). In the making of this film, Diana travelled to various corners of the world—Tokyo and Hokkaido Island, Ireland's Raheen Oak Wood, the redwoods of California, the Avatar Grove on Vancouver Island, British Columbia, and UNESCO world site Pimachiowin Aki on the eastern shore of Lake Winnipeg—to meet and share experiences with people engaged in restoration of forests and research demonstrating their value is highest and most essential when left intact.

A second key theme of her work is science-based wisdom for living: her 2013 volume *The Sweetness of a Simple Life: Tips for Healthier, Happier, and Kinder Living Gleaned from the Wisdom and Science of Nature* (Random House Canada), contains 60 short chapters organized around "Health and Food", "Home and Garden", and "The Larger World". The book concludes with a description of her Bioplan, a constant third theme in all her work.

The foundation of the Bioplan is simply stated—everyone plants a tree a year for six years—and potentially very effective. She knows not everyone can or will do that, but the science is getting behind it; she cited "The global tree restoration potential" in *Science* (365: 76–79 https://doi.org/10.1126/science.aax0848), as a recent example. Diana consults with many schools and other institutions on how to follow her Bioplan. She also has her own forest and garden, a 65-hectare plot she calls Carriglaith near Merrickville, just outside Ottawa, where she and her husband, Christian Kroeger, work hard to preserve rare species of trees. She goes to phenomenal efforts to find these species.

Awards have flowed in. In 2010, she was elected a Fellow by Wings WorldQuest, an international organization "dedicated to recognizing and supporting visionary women" and the following year, the Utne Reader named her one of their 25 Visionaries for 2011. The Royal Canadian Geographical Society elected her to the College of Fellows in 2013 and named her one of 25 women explorers of Canada in 2016. Diana received an honorary doctorate from Carleton University on 11 June 2019. The citation notes that *Call of the Forest* "was nominated for the Rob Stewart Award for Best Science or Nature Documentary Program at the 2018 Canadian Screen Awards. Her peer reviewed work, *Arboretum America: A Philosophy of the Forest*, won the prestigious National Arbor Day Foundation Media Award for an exceptional educational work on trees and forests" (https://newsroom.carleton.ca/2019/diana-beresford-kroeger-receives-honorary-degree-from-carleton-university/). She has been profiled in many newspapers, the *New York Times*, *Winnipeg Free Press*, and *Ottawa Citizen*, to name only a few; interviewed on Baltimore NPR's Marc Steiner Show, by the CBC, and other radio stations; in October 2018, Andrew Nikiforuk published a two-part article on her work in *The Tyee*, an independent, online, British Columbian news magazine. As well, Diana has written over 300 scientific and 'popular' accounts of her research for various journals and magazines. (See the Media section of http://calloftheforest.ca/about-diana/ for a partial list.) She gives guest lectures and masterclasses

and is a science advisor for the Archangel Ancient Tree Archive, which works to preserve the Earth's oldest trees through its Champion Tree Project (https://www.ancienttreearchive.org/). How she does all this while managing to live off-line is a wonder—she's not sure how she does it either, but noted that not having the internet is certainly helpful in getting things done!

A final comment: in addition to inspiring people all over the world, she was recently fictionalized as scientist Patricia Westerford in Richard Powers' near-overwhelming novel about the life and times of trees, *The Overstory*, soon to be reviewed in *The Canadian Field-Naturalist*. Space won't allow recounting her story of how she heard about this, but it became yet another means of getting the message out. Clearly, Diana Beresford-Kroeger's work, like all works of nature, will live on in many forms.

BARRY COTTAM
Book Review Editor –
The Canadian Field-Naturalist

The Canadian Field-Naturalist

Minutes of the 140th Annual Business Meeting (ABM) of the Ottawa Field-Naturalists' Club, 8 January 2019

Place and time: Neatby Building, Carling Avenue, Ottawa, Ontario, 7:00 pm
Chairperson: Diane Lepage, President

Fifty-three attendees spent the first half-hour reviewing minutes of the previous ABM, the financial statements, Treasurer's Report, and annual reports of Ottawa Field-Naturalists' Club (OFNC) committees for 2017–2018. The meeting was called to order at 7:30 pm. During the meeting, relevant documents were projected on a screen for the audience's information.

1. Minutes of the Previous Annual Business Meeting (ABM)

It was moved by Lynn Ovenden, seconded by Julia Cipriani, that the minutes of the 139th ABM be accepted as distributed and published in *The Canadian Field-Naturalist* (CFN).

Carried

2. Business Arising from the Minutes

Nil.

3. Communications Relating to the Annual Business Meeting

Nil.

4. Treasurer's Report by Ann Mackenzie

Ann presented a simplified statement of OFNC's major sources of revenue (membership, donations, interest) and the Club's donations and expenses (net of associated revenues) from various club activities. Similar to last year, there was a significant shortfall as we continued to use the proceeds of Violetta Czasak's bequest to further the objectives of the club. How long we can continue to run large deficits before the bequest funds are depleted will depend on interest rates as well as our level of deficit spending.

Subscription fees for *The Canadian Field-Naturalist* increased last year but that increased revenue is deferred until the coming year when the relevant issues are published.

Ann also described some of the electronic technologies and programs that are enabling her and other volunteers to process OFNC financial processes more efficiently, maybe even remotely. The Club increasingly makes payments by direct deposit instead of cheque, and accepts payment by direct bank transfer and credit card.

In response to a question, members were told the budget for 2018–2019 was approved by the Board of Directors at its October 2018 meeting and attached to the minutes, available at http://ofnc.ca/wp-content/uploads/2018/11/OFNC-Board-Minutes-2018-10-15.pdf.

Moved by Ann MacKenzie and seconded by Henry Steger, that the financial statements be accepted as fair representation of the financial position of the Club as of September 30, 2018.

Carried

5. Nomination of the Accounting Firm

Moved by Ann MacKenzie and seconded by Jeff Skevington, that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2019.

Carried

6. Committee Annual Reports

A few highlights from each report were presented by the chair or a representative of each committee. There was a request to make the reports available on the website.

Moved by Lynn Ovenden and seconded by Ann MacKenzie, that the committee reports be accepted as distributed.

Carried

7. Highlights from 2018

a) Christmas Bird Count (Bob Cermak)

The 100th Ottawa-Gatineau Christmas Bird Count (CBC), a joint effort of the Ottawa Field-Naturalists' Club (OFNC) and the Club des ornithologues de l'Outaouais (COO), was held 16 December 2018. The CBC, worldwide since the first in 1900, is the longest running citizen science survey in the world. Data collected by observers are vital for conservationists. It informs strategies to protect birds and their habitat, and helps identify environmental issues with implications for people as well.

b) Safe Wings Ottawa (Anouk Hoedeman)

Anouk provided an update on Safe Wings' pro-

gress in promoting awareness of bird-building collisions and effective solutions. She discussed the importance of monitoring buildings and collecting data and specimens to convince building owners of the seriousness of the problems, and the challenges volunteers face due to widespread misconceptions about preventing collisions and the need to rescue stunned birds. She spoke of the program's unexpected expansion into providing rescue and rehabilitation not only for window collision victims, but for birds requiring care for other reasons as well, due to the high demand for such services.

c) Mer Bleue walk with new Canadians (Jakob Mueller)

At the request of the Ottawa Community Immigrant Services Organization, a nature walk at Mer Bleue was offered to about 30 new Canadians in September. Several members with experience leading walks participated in the event and everyone enjoyed the outing.

8. Nominations for Board of Directors positions

Fenja Brodo presented the slate of candidates nominated to the Board of Directors for 2019:

EXECUTIVE COMMITTEE

Diane Lepage	President
Jakob Mueller	1st Vice President and Chair, Events Committee
Elizabeth Moore	Recording Secretary
Ann MacKenzie	Treasurer

DIRECTORS

Fenja Brodo	Past President
Robert Cermak	Chair, Birds Committee
Owen Clarkin	Chair, Conservation Committee
Edward Farnworth	Representative, Fletcher Wildlife Committee
Catherine Hessian	Member-at-Large
Anouk Hoedeman	Chair, Safe Wings Ottawa
Diane Kitching	Representative, Macoun Field Club
Bev McBride	Member-at-Large
Gordon Robertson	Chair, Education and Publicity
Jeff Saarela	Chair, Publications
Henry Steger	Chair, Membership
Ken Young	Chair, Finance
Eleanor Zurbrigg	Chair, Awards

EX OFFICIO:

Annie Bélair, Editor of *Trail & Landscape*

Dwayne Lepitzki, Editor of *The Canadian Field-Naturalist*

Moved by Fenja Brodo and seconded by Barry Cottam that this slate of nominees be accepted as members of the Board of Directors of the OFNC for 2019.

Carried

Fenja acknowledged Lynn Ovenden's departure from the Board after serving as the Recording Secretary. She warmly welcomed Elizabeth Moore and Bev McBride to the Board. Committee chairs will be approved by the Board of Directors at the January 2019 meeting.

9. New Business and General Discussion

Nil.

10. Presentation: Small Creatures, Big Impact

Jakob Mueller described the seven salamander species that live in eastern Ontario and the important role of salamanders in the deciduous and mixed forests of eastern North America.

11. Adjournment

Moved by Lynn Ovenden, seconded by Eleanor Zurbrigg, that the meeting be adjourned.

Carried

LYNN OVENDEN
Recording Secretary

Annual Reports of OFNC Committees for October 2017–September 2018

Awards Committee

The Awards Committee manages the process to annually recognize those Ottawa Field-Naturalists' Club (OFNC) members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In late 2017, nominations were received and evaluated (see awards criteria at https://ofnc.ca/about-ofnc/awards), resulting in nominees for four awards being recommended to the Board of Directors for approval. Biographies were written for each award recipient for inclusion in the Club's publications and posting on the website. The awards were presented at the annual Awards Night in April 2018. The recipients' names, type of award and rationale for recognition follow below.

- Annie Bélair—Member of the Year for redesigning *Trail & Landscape* as a communication venue for local members.
- Julia Cipriani—George McGee Service Award for dedicated service on Events Committee and other areas of Club activity.
- David Seburn—Conservation Award for a Member for advocacy efforts influencing the decision to ban hunting of Snapping Turtles in Ontario.
- The Teachers of Regina Street Alternative School—Mary Stuart Education Award for connecting their students with nature at Mud Lake.

President Diane Lepage selected Greg Lutick and Adrienne Jex as the recipients of the 2017 President's Prize for improving service of refreshments at monthly meetings.

The Awards Committee thanks Mark Brenchley for helping with awards certificate design and printing.

Awards Committee: Irwin Brodo, Julia Cipriani, Christine Hanrahan, Karen McLachlan Hamilton

ELEANOR ZURBRIGG, Chair

Birds Committee

Birds Committee (11 members, one ex officio, and one observer), Bird Records Sub-committee (11 members), and Bird Feeders Sub-committee (one member and five volunteers) coordinated OFNC bird related activities and directed and encouraged interest in birds within and outside the OFNC area.

Two committee members administered OFNC's Facebook group (2161 members October 2018) which provides a place for club members and prospective members to discuss ideas and exchange information related to all aspects of natural history, club outings, and club initiatives.

A committee member provided weekly provincial (Ontbirds) reports of OFNC area (Ottawa-Gatineau) bird sightings which with photos by local photographers was also provided on the OFNC Facebook and the OFNC website. This same member authored a four-part, four issue, *Trail & Landscape* article "How to find 250 Bird Species in the OFNC Study Area in a Single Year".

Our committee participated in the Ottawa River Watershed Study and the creation of the Lac Deschênes-Ottawa River Important Bird Area (IBA). We liaised with the Innis Point Bird Observatory and recommended financial support for their Osprey web cam and bander-in-charge. We coordinated updates to the Department of National Defence's (DND's) Shirleys Bay causeway access list which currently contains 385 OFNC members.

Birds Committee collaborated with other OFNC committees throughout the year. Our committee members led field trips and participated in Conservation Committee activities such as supporting the Friends of the Carp Hills with their survey and planning for the conservation and public use of Torbolton Ridge land owned by the City of Ottawa. We provided a significant role in OFNC's efforts to introduce new Canadians to OFNC area natural history by partnering with the Ottawa Community Immigrant Services Organization to organize and help lead a field trip at the Mer Bleue boardwalk and area.

Birds Committee and the Club des ornithologues de L'Outaouais organized the 2017 Christmas Bird Count with 133 field observers and 28 feeder watchers finding 60 bird species. The 2018 Seedathon "Big Day" event was held in early fall to raise funds for purchasing seeds for the five OFNC bird feeders. One hundred and thirty bird species were found and $790 (as of 1 August) was raised.

Although the OFNC Falcon Watch is no longer required because the Heron Road nest site is in a safe location, several members keep an informal watch on the nest. Four more Peregrines successfully fledged from this location this year.

BOB CERMAK, Chair

Conservation Committee

A major accomplishment of the OFNC Conservation Committee in 2018 was successfully documenting Red Spruce (*Picea rubens*) at many sites in eastern Ontario. This tree species is considered a key component of climax forests of eastern Canada and yet was apparently largely "missed" in the forest surveys of

eastern Ontario to date. Members of the committee and other interested individuals collaborated to:

- Confirm the presence of Red Spruce is much more abundant and widespread south of the Mer Bleue bog (centred at approximately Anderson Road/Leitrim Road/Highway 417) than was previously known.
- Confirm the presence of Red Spruce at several locations outside of the Ottawa district where it was apparently not previously documented: Hawkesbury, Alfred, near Alfred Bog, Rose Lake, and Vennachar Junction-Denbigh.
- This project was the topic of the October OFNC monthly meeting, and will be summarized in a forthcoming article currently in preparation. Records are being uploaded to iNaturalist as time permits. We anticipate that we will continue to work on this project at a more relaxed pace in 2019 to further resolve uncertainties regarding Red Spruce in Ontario.

It was another busy year for OFNC-Conservation regarding public outreach and active conservation work in the great outdoors. Members of our committee lent their expertise to lead numerous conservation events, including many guided public Nature tours, public lectures, bio-inventories, and attendance/contribution at conservation-related meetings. Our committee members continued to enthusiastically document wildlife near Ottawa and further afield with thousands of observations entered into iNaturalist and other conservation databases.

As in previous years, we met regularly to discuss and plan actions regarding species of conservation concern (both threatened indigenous species, and emerging potentially invasive exotics), habitat conservation/restoration projects, and engaging both naturalists and the general public alike in conserving Canada's natural wildlife heritage. We were pleased to collaborate on conservation work with a number of external organizations and several other OFNC committees throughout the year.

We were pleased to welcome Greg Lutick to the committee this year.

OWEN J. CLARKIN, Chair

Education and Publicity Committee

Storyboards for display at eight sites around the Fletcher Wildlife Garden (FWG) continue to be developed. We now have 24 bilingual stories, eight per season. They are now all laminated so that they can be reused for years. The previous ones on photopaper were unusable after one season.

We held a second Open House at the Resource Centre in collaboration with Jane's Walks. Several members hosted about 100 visitors with drinks, cookies, and tours of the garden. This was approximately double from the previous year.

This year we had two applications for sponsorship to the Youth Summit of Ontario Nature. Both candidates were judged worthy to attend and have done so. Lucy Patterson and Kathy Conlan were again judges at the annual Ottawa Regional Science Fair. They presented three OFNC awards ($100 each) and 1-year club memberships to the winning students.

We hosted numerous group tours of the FWG this year including three tours by home schoolers, seven tours by Scouts/Beavers/Brownies, and two school groups. We also developed seasonal Visual/Audio Scavenger Hunts for use with these groups and one for a tour of Mer Bleue for new immigrants. A flyer was also made for Petrie Island but was never used due to closing of its causeway until 2019. There were also several presentations at a seniors' home, to the DND, and to the Canadian Parks and Wilderness Society (CPAWS).

Bug Day was again a success this year with hundreds of attendees visiting our microscope tables to view insect specimens provide by Fenja Brodo. A callout for volunteers yielded 16 enthusiastic OFNC members who assisted with identifying insects and observing specimens under the microscopes.

Finally, we had one new member confirmed by the Board, Alexandra Brett, with three more possible in the near future. Thanks are extended for the contributions of Mark Brenchley who has stepped down from the committee.

GORDON ROBERTSON, Chair

Events Committee

In 2018, the Events Committee (consisting of Julia Cipriani, Owen Clarkin, Hume Douglas, Bev McBride, Elizabeth Robson-Gordon, and Jakob Mueller) planned or organized field trips, workshops, and presentations for monthly meetings, as well as a Bioblitz-style species inventory. The committee is grateful for the help it received from leaders, volunteers, and experts too numerous to list.

Nine of the club's ten monthly meetings included presentations (the exception was the Annual Business Meeting). Topics ranged from faraway locations (Uganda, Iceland, and Mars), to conservation challenges (freshwater ecosystems, cod stocks, turtles, and Red Spruce), ecology (the importance and role of night), and profiles of taxonomic groups (lichen). The December meeting had 135 people in attendance, the highest for a monthly meeting since the venue moved to the Neatby building several years ago. Of the 48 trips or workshops, primary focusses included birds or birding (19), botany (11), herpetology (three), insects (two), and mushrooms (one), with

the remaining 12 trips devoted to general natural history and miscellaneous topics. The annual Members' Photography Night continued, but was postponed to April and held in a new venue due to some logistical challenges in January. In addition, the committee lent their expertise to the coordination of a species inventory for the Nature Conservancy of Canada's property that forms part of the Kenauk Nature reserve north of Montebello, Quebec. Over two days in July, OFNC members and associated scientists recorded 454 species at the property and revealed opportunities for further study.

The Events Committee continues to face the perennial yet pressing challenge of recruiting and developing new leaders for field trips. If you have ideas for events or are willing to share your interests or expertise, please do not hesitate to get in touch.

JAKOB MUELLER, Chair

Finance Committee

This report covers financial matters during fiscal year 2018, which extended from 1 October 2017 through 30 September 2018. Many of these matters go directly to the Board of Directors for resolution. However, they are mentioned here to give OFNC members a sense of the financial issues that occur.

The budget for FY2019 was prepared by the Finance Committee, based on input from the Board of Directors and analysis by the Finance Committee. It was presented to the Board in September 2018, and approved at the October 2018 Board meeting. The budget forecasts revenues of $146 000, expenses of $195 775, for a deficit of $49 775.

During the 2018 fiscal year, the Board dealt with several financial issues that were not foreseen when the budget for FY2018 was prepared. These were:

- A request by the Innis Point Bird Observatory for $4500, to pay a Head Bander. This was approved;
- A request by a local bird sanctuary to support its new educational programs. This was declined;
- A request by a group sponsoring a clean-up at Mud Lake, for $400 for a barbecue lunch for volunteers. This was declined.

A financial issue which comes up from time to time is whether a particular type of volunteer work should be recognized by granting an honorarium. During FY2018, this arose at the Board in the context of Facebook administrators. The Board decided not to grant honoraria for this activity.

The Treasurer continued her work to improve our systems for bookkeeping, donations, and payments.

KEN YOUNG, Chair

Fletcher Wildlife Garden

Volunteers

The FWG had a productive season in spite of periods of low rainfall and high temperatures. Volunteers working through the summer were joined by several corporate work groups, and students from Carleton University and University of Ottawa to carry out work throughout the property. Habitat preservation and rehabilitation took up the majority of our time, with good progress made on combating a growing list of invasive and noxious plants. Agriculture and Agri-food Canada (AAFC) was particularly helpful in this respect. In 2018, our volunteers put in over 5000 hours of time maintaining and improving the property.

Our annual native plant sale was a great success. The sale is a source of revenue, but most important, it promotes the use of native plants in local gardens. In 2018, we also donated native plants to at least 10 school, community, church, and other demonstration pollinator gardens.

Wildlife

This summer saw an unexpected rise in the number of Monarchs and other butterflies at the FWG. Several volunteers collected and reared eggs and caterpillars and released over 150 mature Monarchs. The release events were witnessed by many volunteers and visitors to the FWG, creating opportunities to chat about conservation issues. In conjunction with Wild Pollinator Partners, we also held two workshops in April to make our highly successful Mason Bee boxes and another in fall to look at the pupae in the boxes (128) before storing them for winter. Jessica Forrest of the University of Ottawa gave a workshop on bees and was on hand at the latter workshop to identify wasp and bee pupae. Three Snapping Turtle nests were identified at the FWG this year, and we had help from the Canadian Wildlife Federation in rescuing eggs from a washed-out nest from the Arboretum.

Pond work

The south bank of the pond is now covered with a variety of native plants, much used by Giant and Black Swallowtail butterflies and Goldfinches. Two benches were installed along the trail to allow visitors observation points. Erosion damage to the path around the pond was repaired early in the season as a safety measure. In October, a contractor was hired to install a drainage trench to prevent future problems. We continued to remove Flowering Rush from the pond.

Backyard Garden

The Back Yard Garden (BYG) continues to be a popular area, and the hard work of our Friday morning volunteer group is much appreciated by visitors. Many photographers and artists visited the BYG to take advantage of the colourful variety of flowers and

birds. Last fall, several trees were removed to maintain favourable sun/shade conditions of the garden.

The Gully

The area between the west end of the pond and Prince of Wales Drive was a focus of much work this summer. Thanks to students from the Algonquin College horticulture program and the initiative and hard work of FWG volunteers, masses of Dog-strangling Vine and Comfrey were replaced with native plants, such as Swamp Milkweed and Joe-Pye Weed. The transformation of this part of the FWG was inspiring to all involved and rewarding to those of us who saw the many Monarchs and other insects there this summer.

The Ravine

Intensive removal of invasive species on the north side of the ravine in 2017 was followed by planting of Bush Honeysuckle this summer. The addition of a bench overlooking the ravine has created a popular vantage point for photographers and birders.

Tours/Visitors

During this summer, the FWG provided tours to a number of youth groups. A series of questionnaires about plants, animals, birds, and insects that can be found at the FWG were used for the first time this summer by young visitors to look for as they walk along the trails. Storyboards have been placed around the property with seasonally appropriate photos to emphasize the diversity of flora and fauna at the FWG. Visitors to the Resource Centre now enjoy new stand up displays that include actual wildlife specimens.

TED FARNWORTH, Committee Member

Macoun Club

Macoun Field Club activities take place almost every Saturday from September through June, except for public holidays. During 2017–2018, Committee members organized and supervised 17 indoor meetings, at which the children and young people (ages eight to 17) gathered for presentations on mainly zoological and ecological topics. Committee members also planned and led 18 field trips, mostly to either the Club's long-term nature-study area in Ottawa's western greenbelt, or to Gerry Lee's wild lands in the Pakenham Hills of Lanark County (from 1967–2002 known to Macoun Club members as Mary Stuart's property). Part of one field-trip involved a joint outing with the OFNC, at Brewer Park Pond, and one special astronomy trip was held at night. Additionally, there was one overnight camping trip to Gerry Lee's land.

Committee and Macoun Club members hosted the annual nature quiz at the OFNC Awards Night.

The Macoun Club quietly celebrated its 70th year. Committee members maintained an up-to-date, illustrated record of all events on the Club's website, now hosted by the OFNC, and produced the monthly newsletter and issue No. 72 of the Club's annual magazine, *The Little Bear*.

ROBERT E. LEE, Chair

Membership Committee

The distribution of Club membership for 2018 on 30 September 2018 is shown in the table below, with the corresponding numbers shown in brackets for 30 September 2017. "Other" represent mostly affiliate organizations that receive complimentary copies of the Club's publications. There was a slight decrease in membership in 2017. Members within 50 km of Ottawa comprised 713 of the Canadian membership of 827. Families of children in the Macoun Club are given complimentary membership to encourage interest in the Club in the longer term.

HENRY STEGER, Chair

Publications Committee

The Publications Committee manages publication of the Club's scientific journal *The Canadian Field-Naturalist* (CFN), the Club's regional publication *Trail & Landscape*, and Special Publications. Committee members were Annie Bélair (Editor, *Trail & Landscape*), Dan Brunton, Carolyn Callaghan, Paul Catling, Barry Cottam (Book Review Editor, CFN), William Halliday (Online Journal Manager, CFN),

	CANADIAN		USA		OTHER		TOTAL	
Individual	385	(399)	7	(6)	0	(0)	392	(405)
Family	314	(316)	0	(0)	1	(0)	315	(316)
Student	23	(24)	0	(0)	0	(0)	23	(24)
Trail & Landscape	2	(2)	0	(0)	0	(0)	2	(2)
Honorary	24	(25)	0	(0)	0	(1)	24	(26)
Life	40	(41)	3	(3)	1	(1)	44	(44)
Other	24	(24)	0	(0)	1	(1)	25	(25)
Macoun Club	15	(19)					15	(19)
TOTAL	827	(848)	10	(9)	3	(3)	840	(860)

Karen McLachlan Hamilton, Diane Kitching, Dwayne Lepitzki (Editor-in-Chief, CFN), Amanda Martin (Assistant Editor, CFN), Jeff Saarela (Chair), David Seburn, Ken Young, and Eleanor Zurbrigg. Frank Pope resigned from the committee in December 2017, after many years of committee participation.

Trail & Landscape

Four issues of *Trail & Landscape* were published: 51(4) (October–December 2017), 52(1) (January–March 2018), 52(2) (April–June 2018) and 52(3) (July–September 2018). Feedback from Club members on the new, all-colour format of *Trail & Landscape* (launched with vol. 51(3)) continued to be extremely positive and encouraging.

The Canadian Field-Naturalist

Three issues of *The Canadian Field-Naturalist* were published: 131(2), 131(3), and 131(4). In 131(3) a new type of content was introduced in *The Canadian Field-Naturalist*. "Great Canadian Field-Naturalists" recognizes individuals who made significant contributions to our knowledge of the natural history of Canada. Criteria for recognition were established, and Great Canadian Field-Naturalist tributes were published for James Fletcher and John Macoun. Also this year, the James Fletcher Award was established. The award recognizes the best paper published in CFN in a particular volume. The first award, for CFN Volume 130 (2016), was announced in 131(3). Francis Cook, who served as Editor of CFN for more than 30 years, was appointed to the Order of Canada in 2018.

Subscription fees for institutional subscribers were increased, based on a survey of fees for journals similar to CFN, and the fact that our production costs have increased without subscription increase for a long time. Revised author guidelines for preparing manuscripts for CFN were finalized and published online at http://www.canadianfieldnaturalist.ca/public/journals/1/CFNAuthorInstructions.pdf.

The committee completed the consolidation process of back issues of *The Canadian Field-Naturalist*. A small team convened in spring 2018 and moved the back issues, which were stored in the Red Barn on the Farm during the autumn and winter of 2017–2018, to the Fletcher Interpretive Centre, and then sorted and organized the material. Given limited demand for hard copy back issues of the journal, only a small subset of the available back issues was retained; the material is now being stored by Annie Belair. The surplus material was recycled.

Ottawa Field-Naturalists' Club Research Grants

2018 was the fourth year of the Ottawa Field-Naturalists' Club Research Grants program. Research grants support field-based research activities that reflect and promote the Club's objectives within eastern Ontario and/or western Quebec, focussed particularly upon the Club's study area. A total of $15 000 is available each year to fund research proposals. The application deadline was 15 January 2018. A subcommittee convened and chaired by Dr. Tony Gaston reviewed all proposals and submitted funding recommendations to the Board of Directors. A list of recipients of 2018 Research Grants was published in *Trail & Landscape* 52(3).

JEFFERY M. SAARELA, Chair

Safe Wings Committee

2017–2018 was Safe Wings Ottawa's first year as a standing committee of the OFNC, after several years as a program of the Birds Committee. This committee works to address the problem of bird-window collisions through research, education, and rescue.

Between 1 October 2017 and 30 September 2018, Safe Wings volunteers:

- regularly monitored 75+ buildings during spring and fall migration
- documented ±2300 window collisions
- rescued 493 live birds following window collisions
- answered approximately 2500 phone calls
- admitted 610 birds with various types of injuries to our own facility
- provided rescue assistance and transported hundreds of injured birds to Safe Wings and to the Wild Bird Care Centre.

In addition, we produced a brochure on window collisions, and completed a draft Ottawa Bird Strategy. Our outreach efforts led to the adoption of bird-friendly design guidelines by Public Services and Procurement Canada (PSPC), the National Capital Commission, and the City of Ottawa (currently in development), as well as Carleton University and the University of Ottawa. Environment and Climate Change Canada also began working on several initiatives to address collisions.

In 2017–2018, Safe Wings volunteers' workload expanded significantly due to several factors: public awareness of bird-building collisions continued to increase; the City of Ottawa began referring calls about all injured birds to Safe Wings; the Ottawa Valley Wild Bird Care Centre further reduced its own phone hours and increased its reliance on Safe Wings to provide preliminary care to injured birds; and several high-profile, non-collision bird rescues drew media attention, namely the Great Horned Owl family on Petrie Island, a Wild Turkey in downtown Ottawa, the Bluesfest Killdeer (although we did not directly intervene), and a Northern Flicker found hung by its neck.

Safe Wings also generated media coverage for

its building monitoring program, its annual bird display at City Hall, the National Art Centre's not-bird-friendly renovation, the National Gallery of Canada's failure to address collisions, PSPC's efforts to retrofit the C.D. Howe building, and Snowy Owls being hit by cars.

ANOUK HOEDEMAN, Chair

Treasurer's Annual Report, 2018

The Financial statements for the year ended 30 September 2018 have been prepared by our accounting firm, Welch LLP based on a review they conducted of our financial records. We do not get our books audited.

There are no major changes to report from last year to this year because many of the trends remain. We are continuing to run deficits as we use the proceeds of the Czasak bequest to further the objectives of the club. During the year we were able to provide a $10 000 donation towards the publication of *The Birds of Nunavut* by Anthony Gaston, continuing the OFNC's long history of support for the natural history of the Arctic. For the third year we gave $5000 to the Ottawa-Carleton District School Board to enable more children to spend time at their Outdoor Education Centres. Support was also provided for a bird bander at Innis Point. Both the Invasive Plant Council (annual meeting) and the Entomological Society (Bug Day) also received support.

In the interests of good governance your Board reviewed the length of time we could run substantial deficits before the bequest funds were depleted. How long this takes will depend on interest rates as well as our level of deficit spending. An analysis of these two variables was carried out thanks to a tool developed by Catherine Hessian. If we continue with our current level of a $80 000 difference between our interest income and budget deficit, then we would be back to our pre-bequest investment level of $500 000 in 19 years. Using this tool the Board can more prudently consider any significant expenditures that might be proposed in the future. For example, if we donated $100 000 for the purchase of property then we would have used up the bequest in 17 years.

Last year we reported that we would be closing several funds as part of streamlining of our financial systems and record keeping. This will be the last year that the Seedathon Fund, Anne Hanes Memorial Fund, and the De Kiriline Lawrence Fund will be shown in the statements. These funds have been netted to zero as they are incorporated into the General Fund of the club. The two Macoun funds have been merged into one.

As a result of increased subscription fees for the CFN journal there was a significant increase in revenue from that source. Most of this was deferred until next year because the issues it relates to were not yet published. The apparent increased revenue showing this year reflects deferral rates between the last couple of years.

We are increasingly using technologies and programs to enhance the efficiency of our financial processes. This past year we started making payments using direct deposits rather than cheques. Increasingly payments we receive are similarly direct bank transfers. We also did a trial to accept credit card payments at the Fletcher Wildlife Garden plant sale. That worked so well we decided that we would promote it for 2019.

This has been my second full year as Treasurer. I am pleased that we were able to provide the Board with the financial statements for their consideration at their December meeting prior to presenting them at the Annual Business Meeting in January. It is my intention to continue that practice into the future.

In undertaking my tasks I have been greatly assisted by the club financial/administrative team of Ken Young (Chair Finance, CFN invoices, CFN-by-issue reports), Catherine Hessian (Investments, mail and bank deposits), Tanja Schueler (Paypal deposits), Bob Berquist (Donation Receipts), Eleanor Zurbrigg (CFN Subscriptions), and Henry Steger (Membership). Professional advice and services were provided by Katryna Coltess (bookkeeping), Sue Anderson (Investments), and Eric Leibmann (Accounting Review).

Motions:

Moved that the financial statements be accepted as a fair representation of the financial position of the Club as of September 30, 2018.

Moved that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2019.

ANN MACKENZIE, Treasurer

Approved final statements available online at: https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/2337/2217.

The Canadian Field-Naturalist

The Ottawa Field-Naturalists' Club Awards for 2018, presented February 2019

Eleanor Zurbrigg, Irwin Brodo, Julia Cipriani, Christine Hanrahan, and Karen McLachlan Hamilton

On 23 February 2019 members and friends of the Ottawa Field-Naturalists' Club (OFNC) gathered for the Club's Awards Night at St. Basil's Church in Ottawa to celebrate the presentation of awards for achievements in the previous year. Awards are given to members or non-members who have distinguished themselves by accomplishments in the field of natural history and conservation or by extraordinary activity within the Club. Four Club awards were presented for 2018, for: (1) a four-part series on birds in *Trail & Landscape*, (2) long time service managing the Club's membership program, (3) establishing and expanding Safe Wings Ottawa, and (4) nature-based education in Ottawa. As well, a President's Prize was presented.

Member of the Year: Gregory Zbitnew

This award is given in recognition of the member judged to have contributed the most to the Club in the previous year.

In 1977, two local birders, Paul Matthews and Richard Poulin, wrote a series of articles for *Trail & Landscape*, on how to find 200 species a year in the Ottawa area. Fast forward to 2017 when a suggestion was made to update those articles for *Trail & Landscape*. Gregory was asked if he was willing to do this and fortunately for us, he agreed. The result is a comprehensive survey entitled: "How to find 250 bird species in the OFNC study area in a single year".

It is no surprise that a dominant interest for OFNC members is birding. These articles have proven exceptionally valuable for all who are keen on birds whether serious birders or casual observers. Even those whose interests may lie elsewhere will find much to enjoy in this excellent series. A nod should also be given to the outstanding photos by Jacques Bouvier accompanying the articles.

The articles were published in 2018, Volume 52, one per issue starting with Number 1, and culminating with issue Number 4. Along the way, Gregory gave us informative, well-researched, valuable, and eloquent advice and suggestions on how, when, and where to look for birds.

A preamble in the first article talks about "Laying the Foundation" and covers how to find news of recent observations (for example, by checking eBird), and what comprises the OFNC study area. It includes definitions of "common", "uncommon", "rare", and other useful and important points.

Every article focusses on the birds that can be reasonably found in the four seasons covered by each of the different issues. The best locations are highlighted, but not ignored are many other less-visited, excellent spots in which to search for birds. Suggestions as to where some of the seasonal specialties might be found prove especially useful. For example, in issue Number 1, a section called "Chasing Winter Birds" provides tips on where one might see winter finches, Bohemian Waxwings, some of the winter raptors, and other groups of birds more likely to be seen in winter.

Each article also gives a list of "Important Target Birds" to look for during the particular season. These lists include the uncommon to rare species that may be difficult to find but should be found with some effort. As Gregory notes, it "excludes the very rare species" that cannot reliably be predicted.

In the last issue, Number 4, Gregory provides two excellent summaries in the form of tables. In his own words, Table 1 shows the "appropriate activities/places for birding each week" through the year. Table 2 is a list of all the target species "with their usual habitat and the usual time that you can expect to see them". Therefore, at a glance, it is easy to find a bounty of relevant information to help plan birding activities.

The sheer amount of work that Gregory put into these four lengthy articles is staggering. It is clearly a labour of love, and reveals a solid and deep knowledge of the world of birds. A wealth of information is contained within this significant work. These articles will become an essential tool for anyone interested in birding, for many years to come. Indeed, they are al-

ready proving very popular.

In addition to preparing the above articles, Gregory also maintains and distributes the OFNC weekly online birding report. And as if all that is not enough, Gregory also leads birding trips for the OFNC throughout the Ottawa area.

For all these reasons we are more than proud to present Gregory Zbitnew with the OFNC Member of the Year award for 2018.

(Prepared by Christine Hanrahan)

George McGee Service Award: Henry Steger

This award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

It was very fortuitous in late summer 2001 that Henry Steger was retiring soon, and after seeing an article in the *Ottawa Citizen*, dropped by and took an interest in the Fletcher Wildlife Garden (FWG) and joined the OFNC. He met David Hobden, then Chair of the Garden's Management Committee, at an OFNC monthly meeting in early 2002 and offered to volunteer.

Henry's background is in chemistry and mineral processing. His interest in botany came about by serendipity in 1981 and he has pursued it since. So upon his retirement, the FWG seemed a perfect way to follow this interest and he joined the FWG Management Committee in 2002. Apart from his role on the Management Committee, serving as Chair in 2013, he developed a new database for the bird and wildlife sightings at the FWG (computerized almost 2800 hand-written entries recorded between April 1990 and December 2017). He also developed a database for the FWG library. He participated in planning the renewal strategy for the Amphibian Pond and, more recently, in the replanting and weeding around the Amphibian Pond. He continues to help at the annual native plant sales and provides expertise on native species. Henry continues to be a member of this committee, which would make it 17 years and counting.

Henry joined the OFNC Board of Directors as a member at large in 2004 but also was a supportive voice for the FWG at Board meetings. In 2006, when the Membership Committee was about to lose its Chair, Henry graciously accepted the position. In doing so, he inherited a database system that was in desperate need of an update. Undaunted, Henry took up the challenge and developed a new system in Microsoft Access that was tailored to the needs of the Club. As Chair, Henry maintains and updates the database on an ongoing basis due to membership changes, mostly renewals and non-renewals, but has also updated the program itself as new features were needed, for example, going to membership renewal by email. He prints the *Trail & Landscape* (T&L) mailing labels quarterly, manages the emails to members giving them the latest information on upcoming monthly events, and in 2017 created and now updates the list of Club members who want access to the Shirleys Bay causeway.

Henry is also responsible for the "Welcome New Members" seen in every issue of T&L and its "Golden Anniversary Membership List" that appears annually in the second issue. Throughout the years, Henry has written several articles for T&L. In 2010 and then in 2018 he wrote about his struggles with aster seeds collected on a mature plant in one season not growing into that same plant. Then in 2016 his article about the Tubercled Orchid was an intriguing account of his 16 year hunt for this elusive species.

In 2015 when both OFNC Vice-President positions were left vacant, Henry agreed to fill one positon until others could be found. He served as OFNC Vice-President in 2015–2016.

Henry has an analytical mind, is keenly observant and is willing to express his opinions. So, when Henry speaks at Board meetings, you can be sure that it was well thought out and important enough to him to contribute to the conversation. His Jack-of-all-trades skillset was honed throughout his career, making him willing and able to tackle the varied tasks necessary to the Club. That day in 2001 may have been fortuitous, but it has been a real boon for the OFNC. Congratulations Henry for a well-deserved award.

(Prepared by Karen McLachlan Hamilton)

Conservation Award—Member: Anouk Hoedeman

This award recognizes an outstanding contribution by a member in the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District.

For 2018 we are recognizing the initiative and commitment of Anouk Hoedeman for establishing and expanding Safe Wings Ottawa, a program focussed on bird collision research, education, prevention, rescue, and short-term care.

Anouk is well known for her work with the OFNC Birds Committee, including the Falcon Watch. She launched an Ottawa chapter of the Toronto-based FLAP (Fatal Light Attraction Program) in 2014, which later evolved into Safe Wings Ottawa, a separ-

ate organization that operates as a committee of the OFNC.

Safe Wings estimates that 250 000 birds collide with glass every year in Ottawa. Anouk and her group document about 2000 to 3000 of these—the rest go unnoticed or unreported. Many dead birds are eaten by scavengers or discarded, while many injured ones are taken by predators or fly away to die elsewhere.

Safe Wings has a core team of about 15 dedicated volunteers who monitor buildings to collect data and dead bodies, rescue birds, and do what is necessary to support one another and the work they do. Anouk and her fellow volunteers have worked hard to build key relationships with groundskeepers, security guards, and maintenance staff at various buildings downtown and in other areas of the city. As they search every nook and cranny that could shelter a bird, they also educate passersby and encourage them to rescue injured birds and report window collisions. Dozens of other Safe Wings volunteers offer their support by transporting birds or helping with other tasks.

Safe Wings volunteers also conduct outreach activities, make presentations to various groups on preventing bird collisions, and provide advice on designing bird-friendly buildings and on retrofitting existing buildings. Anouk's personal efforts have resulted in the National Capital Commission, Public Services and Procurement Canada, the University of Ottawa, and Carleton University adopting bird-friendly design approaches. In addition, she initiated the City of Ottawa's development of bird-friendly design guidelines, which are expected to come into effect this year.

As a result of its reputation, Safe Wings now receives thousands of calls every year for rescue support from individuals and organizations throughout eastern Ontario and western Quebec, including the City of Ottawa, the Ottawa Valley Wild Bird Care Centre, and even the Cornwall SPCA, to name a few.

Because there is such a demand for help, especially outside the Wild Bird Care Centre's operating hours, Anouk obtained federal and provincial rehabilitation permits so she could provide medication, fluids, and other life-saving treatment to injured and sick birds. In 2018, Anouk cared for 742 patients on the third floor of her home, which has been transformed into a short-term rehabilitation centre set up with a variety of cages to accommodate and keep birds safe, warm, and fed until they can be released or transferred to the Wild Bird Care Centre. All of this care also requires keeping the space clean, organized, and stocked with supplies ready for injured birds which may arrive at any time. It all makes for unpredictable demands on her time, and a steep learning curve to determine how to handle different species ranging from hummingbirds to raptors.

We are pleased to recognize the commitment and work of Anouk Hoedeman with this Conservation Award.

(Prepared by Julia Cipriani)

Mary Stuart Education Award: Bill McMullen

This award is given to a member, non-member, or organization, in recognition of outstanding achievements in the field of natural history education in the Ottawa Region.

This year's Mary Stuart Education Award goes to Bill McMullen, a teacher at the Trillium Public School in Orléans on the eastern edge of Ottawa. Bill grew up in a rural community in the Kawartha Lakes region of central Ontario. There, he was able to spend his childhood years exploring the local forests and fields developing a strong interest in the natural world. As a primary school teacher, he found that he could pass on that passion to his students.

On field trips and in the classroom, Bill teaches his young students to be observant of the world around them, and to explore even the small nooks and crannies in search of stories that nature can tell us and to experience the "quiet" of the woods. He teaches them the importance of the environment and the interrelationships between humans, plants, and animals and encourages them to feel they can be a steward of the Earth. Although Bill is an English and math teacher, his knowledge of the natural world gives him the tools he needs. For example, he educates his charges by setting up orienteering courses and taking them skiing, snowshoeing, and hiking. He has even taught children astronomy using his personal telescope.

Bill is also a talented and dedicated nature photographer, spending many hours in the field, especially at the MacSkimming Outdoor Education Centre, photographing plants, mushrooms, and wildlife. He often makes videos to show phenomena that occur after school hours or over a long period of time at the MacSkimming Centre (such as a Monarch Butterfly emerging from a chrysalis, or wildlife that passes by a video cam set up on a trail over a period of three months). He incorporates his photos and videos into his own lessons as often as he can and offers them to other teachers at his school to use with their own classes. He also generously shares these videos online. Bill has donated many of his photos and videos to the MacSkimming Centre for their education programs and also gives students instruction on nature photography. He has also led evening walks

with school children to see and hear owls, resulting in experiences some youngsters will cherish their entire lives.

By sharing his experience and experiences with his students, Bill McMullen is an example of the kind of teacher who makes a difference. His students are better equipped to understand the conservation issues of the day, hopefully someday translating that appreciation into action for the benefit of the natural world. The Mary Stuart Education Award is a fitting tribute to his vision, skill, energy, and dedication.

(Prepared by Irwin Brodo based on input from staff at the Ottawa-Carleton District School Board)

President's Prize: Ann MacKenzie

This award is given at the President's discretion in recognition of a member for unusual support of the Club and its aims.

The Ottawa Field-Naturalists' Club is blessed to have members with an interest in natural history but with expertise that serves the Club in areas of management and administration. Ann Mackenzie is such a person. She has served the Club very well in the role of President (2012–2013), Past President (2014–2016), and Treasurer (since 2017). I thank her for this.

However, I am recognizing Ann for her on-going work on the Club's financial sustainability and for her dedication to promote financial professionalism and accountability within the Club. If one reviews how the Club's financial operations have changed, there is a constant theme. That is, Ann has striven to enhance the Club's awareness of its financial responsibilities and execution. Today's Club financial procedures and policies have been modernized and in some areas revolutionized.

Before Ann became President, the Club was running unsustainable deficits. Yet there was no attempt to address this issue. Ann dared to suggest an increase in annual fees for the first time in almost 18 years. The practice of a separate fee for paper copies of *The Canadian Field-Naturalist* was implemented. And she fully supported the project to put *The Canadian Field-Naturalist* online to reduce costs.

In November 2015, Ann responded to an announcement of changes to the Ontario *Not-for-Profit Corporations Act* with a review and update of the long-obsolete Articles and By-Laws of the Club's Constitution. This also included a call for all Club committees to update their Terms of Reference. The job is not over. The proclamation of that Act has been delayed.

The receipt of a large bequest from Violetta Czasak led to Ann's recognizing future potential problems with regard to financial management and transparency. She subsequently developed an OFNC Investment Guidelines Policy and initiated the development of Club policy to administer bequests. The latter has supported local community projects in natural history and scientific research projects and has brought increased public recognition for the Club.

Each January the Board of Directors has first-time members. Ann, and probably only she, recognized the need for a guide to help these members become familiar with their roles and expectations. She published the March 2018 Directors' Handbook that all Directors have access to online.

Lastly, Ann has changed how the office of the Treasurer operates. In the past, the Treasurer did it all by his/herself. Within the last year, she brought in "new" volunteers to assist with investment management and the receipt of monies from membership and donations. Hopefully they will stay in the Club and make other contributions in future. It must also be mentioned that Ann has brought in online payment by the Treasurer of financial claims from Club members and the automated printing of income tax receipts for donations.

I wish to award Ann the President's Prize for 2018, with very best wishes and congratulations.

(Prepared by Henry Steger and Diane Lepage, President)

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Club des naturalistes d'Ottawa

The Ottawa Field-Naturalists' Club

FOUNDED 1863 (CURRENT INCORPORATION 1879)

Patron

Her Excellency the Right Honourable Julie Payette, C.C., C.M.M., C.O.M., C.Q., C.D.
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The objectives of this Club shall be to promote the appreciation, preservation, and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining, or restoring environments of high quality for living things.

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The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing Arctic and boreal issues. Qualifying authors should make their application for assistance from the fund at the time of their initial submission.

COVER: Collared Pika (*Ochotona collaris*) in the Ogilvie Mountains at km 158 of Dempster Highway (65.078786°N, 138.360606°W), north of Tombstone Territorial Park, northern Yukon. Aerial and ground surveys were conducted in July 2018 to document occurrence and general habitat suitability of this cold-adapted, at-risk Beringian species. See article in this issue by Syd Cannings *et al.*, pages 130–135. Photo: Jeffrey H. Skevington, 11 July 2018.

The Canadian Field-Naturalist

Roadkill of Eastern Newts (*Notophthalmus viridescens*) in a protected area in Quebec

David C. Seburn[1,*], Elena Kreuzberg[2], and Leah Viau[2]

[1]Seburn Ecological Services, 2710 Clarenda Street, Ottawa, Ontario K2B 7S5 Canada
[2]Canadian Parks and Wilderness Society, Ottawa Valley Chapter, 15 rue Taschereau, suite 240, Gatineau, Quebec J8Y 2V6 Canada
[*]Corresponding author: davidseburn@sympatico.ca

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Abstract

Roadkill is a threat to populations of many amphibian species, including Eastern Newt (*Notophthalmus viridescens*), which is widespread in eastern Canada and the northeastern United States. Little is known about the level of road mortality experienced by dispersing Eastern Newts in Canada. During extensive road surveys from May to October 2016 and 2017, 279 dead Eastern Newt efts were found on roads in Gatineau Park, Quebec. We found 107 dead Eastern Newts along a 425 m section of road in 2016, but only 30 dead individuals at the same location in 2017. Thus, although the amount of roadkill can vary annually, it may pose a significant threat to the species in some areas.

Key words: Eastern Newt; *Notophthalmus viridescens*; road ecology; salamander; hotspot; Gatineau Park

Introduction

Roadkill is a threat for many species of amphibians (Ashley and Robinson 1996; Andrews *et al.* 2008), and they are often the vertebrate group most commonly killed on roads (Ashley and Robinson 1996; Smith and Dodd 2003; Glista *et al.* 2008). Traffic mortality can have a negative effect on amphibian populations (Fahrig *et al.* 1995; Rytwinski and Fahrig 2012). Although roadkill numbers are often greatest for frogs and toads, roadkill can also be a threat for salamanders (Clevenger *et al.* 2001; Gibbs and Shriver 2005; Pagnucco *et al.* 2012). Salamanders may remain immobile on roads when a vehicle approaches, increasing their risk of being run over (Mazerolle 2004). Mortality of >10% of the adult population of Spotted Salamanders (*Ambystoma maculata*) can lead to population decline and possibly extirpation (Gibbs and Shriver 2005).

Here we report on substantial roadkill of Eastern Newt (*Notophthalmus viridescens*), a species widespread in eastern Canada and the northeastern United States (Cook 1984). Eastern Newt is a pond breeding salamander with a complex and variable life cycle. The typical life cycle of Eastern Newt includes four distinct stages: egg, aquatic larva, terrestrial juvenile or eft, and adult (Gill 1978). After larvae transform, the juvenile eft stage disperses from the breeding ponds in late summer and early fall (Gill 1978). The eft stage can last for three or more years (Healy 1974), after which maturing efts return to breeding ponds (Hurlbert 1969). Adults may remain in aquatic habitats or hibernate on land (Hurlbert 1969; Gill 1978). The eft stage is the primary growth and dispersal stage in the life cycle, whereas emigrating adults are believed to return to the same breeding ponds repeatedly (Gill 1978). It is unclear how far efts can disperse, but they have been documented to move up to 80 m in a single night (Roe and Grayson 2008) and take up to a year to migrate 800 m (Healy 1974, 1975). The multi-year maturation and dispersal period allows Eastern Newts to colonize newly formed and distant wetlands (Semlitsch 2008) and represents a vulnerable life history stage (Gill 1978). When migration or dispersal routes cross roads, mortality can occur.

Methods

Road surveys were conducted by car in Gatineau Park, Quebec (45.5°N, 75.8°W) along Meech Lake Road, Gatineau Parkway, Dunlop Road, and Fortune Lake Parkway for a total of ~20 km. Gatineau Park covers an area of 36 131 ha and is managed by the National Capital Commission (NCC 2005). Most of the roads within the park date back to the 1950s or earlier (NCC 2005), but upgrades have occurred over the last several decades. All roads surveyed have

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

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existed for several decades and were paved, two-lane roads. Roadside habitats varied along the roads, but typically the shoulder was narrow with adjacent forests coming within a few metres of the road.

The car was driven at ~30–35 km/h and two surveyors participated in each survey, scanning both the road surface and road shoulder. All dead animals were removed from the road or road shoulder to prevent double counting in a subsequent survey. Surveys were conducted in the morning before scavengers could remove all the roadkill from the previous day or night. Surveys were typically conducted twice a week. Surveys were not conducted during heavy rainfall, but were conducted during light to moderate rain. In addition to driving surveys, walking surveys were conducted at eight locations in the park along the survey route. Walking survey locations were not randomly selected, but based on proximity to designated parking areas in the park to ensure safe parking as well as safety for walking along the roads. Each walking transect was ~90 m in each direction from the stopping point, but extended if high numbers of roadkill were observed. All vertebrate species were recorded, but only results for Eastern Newt are presented here.

Weather data from the closest weather station, Chelsea, Quebec, were obtained to compare rainfall patterns with observed roadkill. On dates where no weather data were available from the Chelsea station, data were obtained from the Ottawa International Airport station, ~25 km to the southeast.

Results and Discussion

We conducted 37 surveys from 12 May until 3 October 2016 and 32 surveys from 15 May to 16 October 2017, for a total of 69 surveys. We found 150 dead Eastern Newts in 2016, and 129 in 2017, for a total of 279. All of the dead Eastern Newts were juveniles (efts). Dead Eastern Newts were found on the road from 18 July to 3 October in 2016, and from 15 May to 8 October in 2017 (Figure 1). The peak mortality events were 36 Eastern Newts on 28 July 2016 and 30 Eastern Newts on 5 June 2017 (Figure 1).

High counts of dead Eastern Newts likely coincide with peak dispersal events, which usually occur in late summer following rains (Gill 1978; Paton *et al.* 2000; Leclair *et al.* 2005). The peak mortality event on 28 July 2016 does not appear to be connected to rainfall as there was no rain on 28 July or the two previous days, although there was 5.2 mm of rain on 25 July (Government of Canada 2019). Rainfall data are missing for the first five days of June 2017, but only 1.0 mm of rainfall was recorded on 4 June 2017, at the Ottawa International Airport. No rainfall was recorded on 3 June and only 0.2 mm on 2 June 2017.

Over 90% of Eastern Newts were found during the walking surveys. We found 107 of the 150 (71.3%) dead Eastern Newts in 2016 along a 425-m section of Meech Lake Road. Smaller numbers of dead Eastern Newts were found at other walking survey locations. The main mortality site was associated with a small creek and numerous wetlands. Habitat at the main mortality site was not obviously different from that at other locations in the park, as creeks, wetlands, and forest are widespread, and the park contains 50 lakes and "several hundred ponds" (NCC 2005). A peak of 30 dead Eastern Newts was found in this mortality "hotspot" on 28 July. Secondary peaks occurred on 12 August (15 Eastern Newts) and 18 August (18 Eastern Newts).

Fewer dead Eastern Newts were found in the main hotspot in 2017: only 30 (25.4%) of the 129 individuals found that year. A peak of 11 dead Eastern Newts was found in the hotspot on 29 June; no more than five mortalities were found on other survey days. There are many possible reasons why fewer dead Eastern

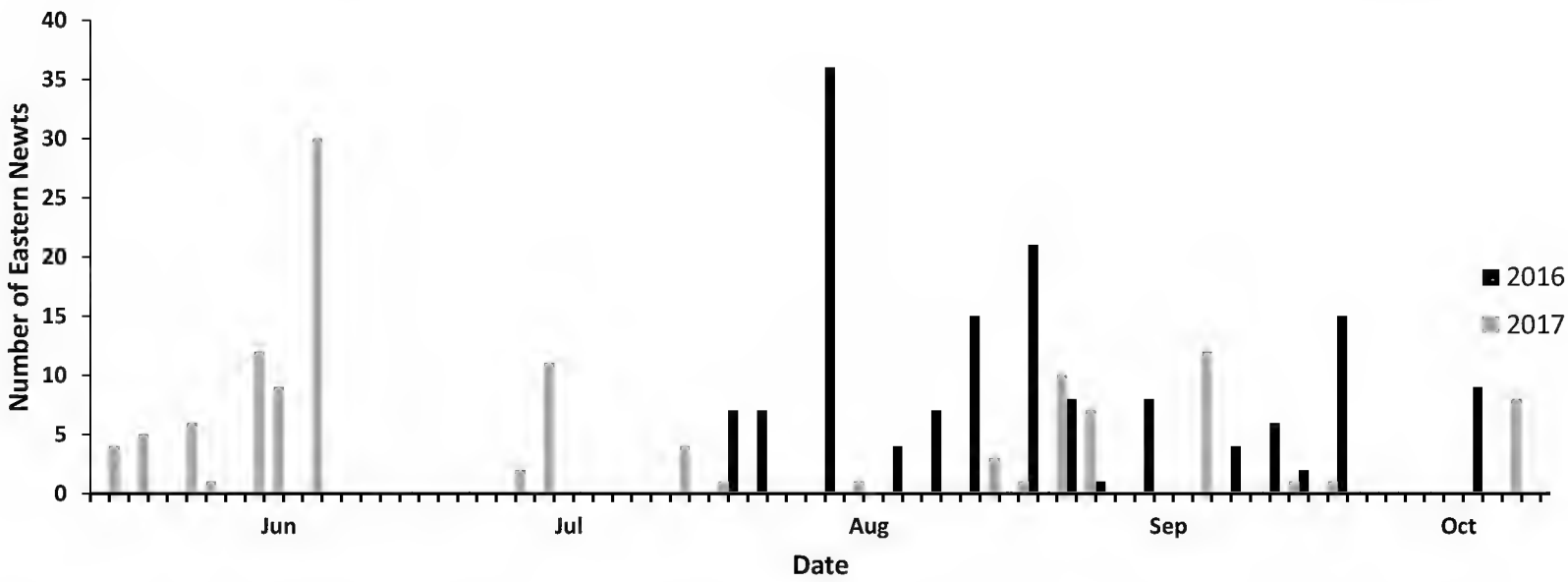

FIGURE 1. Number of Eastern Newt (*Notophthalmus viridescens*) efts found dead on roads in Gatineau Park, Quebec, during road surveys from 12 May to 3 October 2016 and from 15 May to 16 October 2017.

Newts were found in 2017: survey timing not matching peak dispersal events, fewer dispersing efts, or weather conditions limiting dispersal. It does not appear that rainfall is responsible for fewer Eastern Newts being found dead at the main hotspot in 2017, as 2017 was a rainier spring and summer, with 344.6 mm from May to August, compared with only 185.4 mm during the same period in 2016 (Government of Canada 2019).

Over the two years, 137 dead Eastern Newts were found at the main hotspot. Likely many other Eastern Newts were killed there, but not observed, given their small size, obliteration by vehicles, and removal by scavengers. Unlike many other salamanders, Eastern Newts are active during the day (Petranka 1998) when motorists are more likely to travel park roads.

Other researchers have reported significant numbers of dead Eastern Newts on roads. Mitchell (2000) found 182 dead Eastern Newts along a 250-m stretch of road on 4 October 1991 in Virginia. An additional 24 dead Eastern Newts were found at the same site over the course of three subsequent surveys in 1992 (Mitchell 2000). The large number of mortalities in 1991 may have been a chance event, or the result of a large production of efts that year (Mitchell 2000). The results from Virginia are similar to our results from Quebec, i.e., substantially different numbers of observed roadkill at the same site in different years. Such results emphasize the fact that one year of road surveys will not always provide a complete picture of the overall rate of roadkill. Individuals in our study were not measured, but were assumed to be recently metamorphosed juveniles dispersing from the natal wetland.

The population-level effect of roadkill on salamanders is not well known. Our results indicate that many Eastern Newts can be killed on roads in some areas. Although efts likely have a relatively high rate of natural mortality, it is unclear what effect the additive mortality of roadkill has on populations. Further research on this topic is warranted.

Acknowledgements

This study was undertaken by the Canadian Parks and Wilderness Society (CPAWS) Ottawa Valley as part of a larger project on road ecology in eastern Ontario and western Quebec. We thank the numerous volunteers who assisted with the road surveys. CPAWS Ottawa Valley is grateful for financial support from the North American Partnership for Environmental Community in Action, the Clean Tech Internship Program of Colleges and Canadian Institutes, and the Community Environmental Grant Program of the City of Ottawa. A permit to conduct research in Gatineau Park was issued by the National Capital Commission.

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First records of Finescale Dace (*Chrosomus neogaeus*) in Newfoundland and Labrador, Canada

Donald G. Keefe[1,*], Robert C. Perry[1], and Gregory R. McCracken[2]

[1]Department of Fisheries and Land Resources, Forestry and Wildlife Research Division, P.O. Box 2007, Corner Brook, Newfoundland and Labrador A2H 7S1 Canada
[2]Department of Biology, Dalhousie University, 1355 Oxford Street, Halifax, Nova Scotia B3H 4R2 Canada
*Corresponding author: donkeefe@gov.nl.ca

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Abstract

The island of Newfoundland has no official record of cyprinid fishes. Here, we report the discovery of a minnow, Finescale Dace (*Chromous neogaeus*) from four ponds located in a first order tributary of the Exploits River, in central Newfoundland. This finding represents the first record of the species in the province. The location where the species was found is in a localized, central portion of insular Newfoundland, therefore, the most parsimonious explanation for this new record is that it was an illegal, intentional introduction. Such introductions in other provinces have occurred by anglers who felt it would serve as a forage fish for other species. The consequences of this introduction to native species are unknown; however, the dace's local abundance, foraging behaviour, and reproductive capacity are discussed in terms of the interspecific competition with native species.

Key words: Finescale Dace; *Chrosomus*; Goldfish; intentional introduction; interspecific competition; exotic species

Introduction

The province of Newfoundland and Labrador has a very low rate of introduction for exotic fish (van Zyll de Jong *et al.* 2004). There are 28 native freshwater fish species in Newfoundland and Labrador; 15 species can be found in insular Newfoundland with an additional 13 species occurring in Labrador (van Zyll de Jong *et al.* 2004; Table 1). For the island portion of the province there have been five attempts at species introductions. These introductions were all salmonids including Brown Trout (*Salmo trutta*), Rainbow Trout (*Onchorhynchus mykiss*), Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*), and Pink Salmon (*Oncorhynchus gorbuscha*; Table 1). However, of these five introductions only the first two succeeded. These species were introduced by government agencies intending to use stocking programs to enhance freshwater fisheries (Scott and Crossman 1964; Hustins 2007).

The only other account of a species introduction documented for the province is Goldfish (*Carassius auratus*). This species has been reported in three locations, but as yet, has not been substantiated by a government agency. The three alleged locations include Mundy Pond (47.55152°N, 52.73891°W) centrally located in the city of St. John's, a small pond near the town of Heart's Delight (47.78691°N, 53.46752°W), and Janes Pond (47.16617°N, 55.16229°W) located in the town of Marystown. All of these locations are in proximity to urban areas, suggesting the likelihood of intentional release of household aquaria pets. In Labrador, there are no records of exotic freshwater fish.

On 4 June 2010 the provincial department of Environment and Conservation received a request to identify an unusual fish that had allegedly been angled by a sport fisher in central Newfoundland. The examination of a photograph suggested the unknown species was a minnow from Cyprinidae family. The fish was reportedly angled from a pond on a tributary of the Exploits River. A field trip was subsequently planned to verify the report or determine the extent of its presence. Herein we report on the occurrence of an exotic invasive minnow species existing in four ponds of a first order tributary of the Exploits River watershed, central Newfoundland.

Methods

Sample collection

To verify the species present and the extent of their distribution two site visits occurred. The first occurred 4–16 June 2012 and the second 9–17 June 2014. During the latter trip the number of sites

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TABLE 1. A list of native and introduced freshwater fish species of Newfoundland and Labrador, Canada (van Zyll de Jong *et al.* 2004).

Common name	Scientific name	Newfoundland	Labrador
American Eel	*Anguilla rostrata*	+	+
Fourspine Stickleback	*Apeltes quadracus*	+	−
Threespine Stickleback	*Gasterosteus aculeatus*	+	+
Blackspotted Stickleback	*Gasterosteus wheatlandi*	+	−
Ninespine Stickleback	*Pungitius pungitius*	+	+
Atlantic Salmon	*Salmo salar*	+	+
Brook Trout	*Salvelinus fontinalis*	+	+
Arctic Char	*Salvelinus alpinus*	+	+
Lake Trout	*Salvelinus namaycush*	−	+
Lake Whitefish	*Coregonus clupeaformis*	−	+
Round Whitefish	*Prosopium cylindraceum*	−	+
Rainbow Smelt	*Osmerus mordax*	+	+
Sea Lamprey	*Petromyzon marinus*	+	+
Alewife	*Alosa pseudoharengus*	+	+
American Shad	*Alosa sapidissima*	+	+
Atlantic Tomcod	*Microgadus tomcod*	+	+
Banded Killifish	*Fundulus diaphanus*	+	−
Mummichog	*Fundulus heteroclitus*	+	−
Northern Pike	*Esox lucius*	−	+
Lake Chub	*Couesius plumbeus*	−	+
Longnose Dace	*Rhinichthys cataractae*	−	+
Northern Pearl Dace	*Margariscus nachtriebi*	−	+
Longnose Sucker	*Catostomus catostomus*	−	+
White Sucker	*Catostomus commersonii*	−	+
Burbot	*Lota lota*	−	+
Mottled Sculpin	*Cottus bairdii*	−	+
Slimy Sculpin	*Cottus cognatus*	−	+
Logperch	*Percina caprodes*	−	+
Rainbow Trout*	*Onchorhynchus mykiss*	+	−
Brown Trout*	*Salmo trutta*	+	−
Goldfish*	*Carassius auratus auratus*	+	−

*Introduced species.

searched was expanded. Initial samples were taken from four headwater lakes located on the south side of the Exploits River near the town of Bishop's Falls. The lakes are located on a first order tributary (Jumpers Brook 49.02667°N, 55.40216°W: Tributary 1; Figure 1). Jumpers Brook flows into the main stem of the Exploits River (49.02857°N, 55.40164°W), entering the Exploits ~8 km upstream from the Atlantic Ocean (in Exploits Bay). Three of the sampled ponds (Mina 1, Mina 2, and Mina 3) were in close proximity (<1 km) to each other and were both small (surface area <0.10 km^2) and shallow (<2 m depth). The fourth lake, Mina 4 was larger (surface area = 0.35 km^2) and deeper (>4 m depth). Mina 4 was ~2 km upstream from Mina 3. The substrate in each pond was mud with scattered rubble and cobble with emergent grasses surrounding the shorelines. The water was dark in colour, the product of humic conditions. During the 2012 sampling, surface temperatures ranged from 8°C to 10°C. In 2014 the temperatures were between 11°C and 20°C.

During the first sampling event, in 2012, both fyke (FYKE-001-06, 10 mm mesh, Shandong, China) and gill nets (Miller Nets, Memphis, Tennessee, USA) were used. Gill nets were composed of nylon monofilament and each set consisted of two stretch mesh sizes measuring 1.91 cm and 2.54 cm, with the smallest mesh being set closest to the shoreline. Three gill nets were set in Mina 1, two in Mina 2 and 3, and four sets were placed in Mina 4. All gill nets were set perpendicular to the shoreline and were set overnight, for an average of 12 h. Fyke (trap) net exterior netting consisted of 1.91 cm stretch mesh size with front hoop of 1 m through to four cylindrical interior hoops with a tied trap end. These nets were set with a 9.8 m mesh lead extending from the front hoop perpendicular to the shoreline. This lead net also consisted of 1.91 cm stretch mesh size. Three small fyke nets were set in the littoral area of Mina 2. All captured native species were retained for measurement and stomach examinations in the laboratory. A subset of unidentified minnow species were retained and preserved in 95% ethanol.

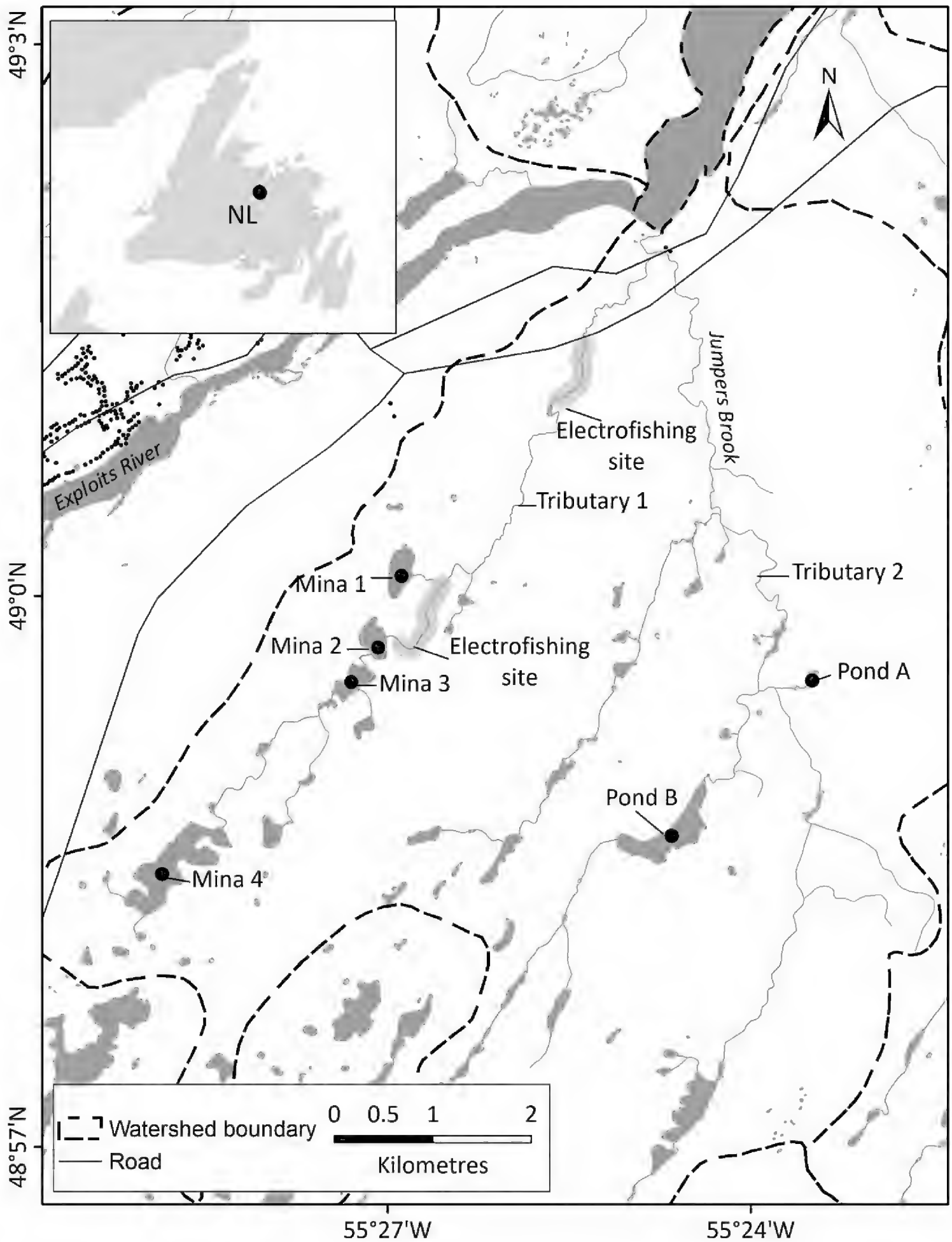

FIGURE 1. The four ponds (Mina 1, 2, 3, and 4) on Tributary 1 from which Finescale Dace (*Chrosomus neogaeus*) was sampled, central Newfoundland. Also shown are the locations of Tributary 2, Ponds A and B, and the locations of the electrofishing stations.

In 2014, sampling was repeated on each of the four ponds originally sampled in 2012. However, instead of gill and fyke nets, minnow pots were used as they have proven to be very effective when sampling dace (He and Lodge 1990). The minnow pots (Gees Feets G-40 Minnow trap, Tackle Factory, Fillmore New York, USA) were constructed of galvanized steel wire with length 42 cm, diameter 23 cm, and square mesh size of 6 mm. Thirty-nine overnight pot sets were placed in ponds Mina 1, 2, 3, and 4 (Table 2). A

TABLE 2. Year and location of sampling, gear type, and numbers set (*n*). Frequency of fish sampled per species for all ponds 4–16 June 2012 and 9–17 June 2014 in central Newfoundland. All sets were overnight.

Year	Location	Gear Type (*n*)	Brook Trout (*Salvelinus fontinalis*)	Atlantic Salmon (*Salmo salar*)	Threespine Stickleback (*Gasterosteus aculeatus*)	Finescale Dace (*Chrosomus neogaeus*)
2012	Mina 1	Gill (3)	29	1	2	10
	Mina 2	Gill (2)	10	9	1	1
	Mina 2	Fyke (3)	7	1	3	—
	Mina 3	Gill (2)	—	—	—	—
	Mina 4	Gill (4)	9	—	—	3
2014	Mina 1	Pot (16)	2	—	26	391
	Mina 2	Pot (9)	—	—	19	24
	Mina 3	Pot (6)	—	—	43	2
	Mina 4	Pot (8)	—	—	15	110
	Pond A	Pot (4)	—	—	—	—
	Pond B	Pot (3)	6	—	29	—

sub-sample of 20 unidentified minnow species were retained, preserved in 95% ethanol, and sent to the Department of Biology at Dalhousie University for genetic-based identification. The sub-sample was a random selection of 10 male and 10 female fish.

To determine if the dace were isolated to just the four ponds or were present in other areas of Jumpers Brook, the lower (1.5 km) and upper (1 km) reaches of Tributary 1 (Figure 1) were sampled by electrofishing. Two small ponds located in another first order tributary were also sampled (Tributary 2; Figure 1). In Tributary 2, four pots were set in Pond A and three pots were placed in Pond B.

Morphometric and subsequent genetic analysis

External morphological measures were recorded for 200 dace chosen from the 2014 collection (Table 3). With the exception of fork length, the morphological characters measured followed those described by Hubbs and Lagler (1958) and Doeringsfeld *et al.* (2004) which included the predorsal length, pectoral fin position, head length, maximum body width, maximum body depth, caudal peduncle depth, interorbital width, gape width, and the upper jaw length.

Species identification using the morphometric data was attempted but proved difficult for several reasons. Given the morphological variability among the sampled dace it was determined that it could be one, or a combination of, three possible species, each sharing very similar physical characteristics. The three species included Northern Redbelly Dace (*Chrosomus eos* (Cope, 1862)), Finescale Dace (*Chrosomus neogaeus* (Cope, 1867)), or their hybrid *Chrosomus eos-neogaeus*. Subsequently, genetic analysis was used for determining species. Nevertheless, this did not remove all the difficulty in identification.

Standard DNA barcoding/sequencing methods using the mitochondrial CO1 gene would not be suf-

TABLE 3. Variation in morphological characters measured from 200 *Chrosomus* sp. collected 9–17 June 2014 from ponds in the Jumpers Brook watershed, central Newfoundland. Measurements as described by Hubbs and Lagler (1958) and Doeringsfeld *et al.* (2004): fork length (FL), predorsal length (PDL), pectoral fin position (PFP), head length (HDL), maximum body width (BYW), maximum body depth (BYD), caudal peduncle depth (CPD), interorbital width (IOW), gape width (GPW), upper jaw length (UJL).

Character	Range	95% CI	Mean	SE
FL	39.00–93.00	64.7–68.7	66.69	0.998
TBM	0.71–10.23	3.64–4.26	3.95	0.157
PDL	18.00–48.10	32.80–34.86	33.83	0.520
PFP	6.30–20.70	13.67–14.50	14.08	0.210
HDL	7.90–21.23	13.81–14.65	14.23	0.214
BYW	4.40–15.10	8.28– 8.92	8.59	0.162
BYD	7.50–20.80	13.35–14.25	13.80	0.228
CPD	0.30–3.60	1.27–1.46	1.37	0.046
IOW	2.50–8.50	5.58–5.97	5.78	0.098
GPW	3.90–13.20	8.01–8.55	8.28	0.136
UJL	1.70–8.90	4.64–4.95	4.79	0.079

ficient for all necessary species identifications in this case. Hybrid individuals (*C. eos-neogaeus*) share mitochondrial DNA with their maternal parent, most commonly *C. neogaeus* (Binet and Angers 2005) and these standard identification techniques would not allow us to distinguish these two complexes. As a result, a method of species identification based on nuclear DNA, in addition to mitochondrial DNA, was required.

Caudal fin tissues were digested with proteinase K (Bio Basic Inc., Markham, Ontario, Canada) for ~8 h at 50°C. DNA was extracted from these tissue digests following a glassmilk approach modified from Elphinstone *et al.* (2003) for use with a Multiprobe II liquid handling system (PerkinElmer, Waltham, Massachusetts, USA). The resulting DNA was examined for quality and quantity by means of gel electrophoresis using a 1% agarose gel.

To perform the species identification, we followed the recommendations found in Binet and Angers (2005) in which the GH and the PEG1/MEST nuclear loci were amplified using polymerase chain reaction (PCR). The resulting PCR products were visualized on a 2% agarose gel and examined for band combination and size to detect the presence of *C. neogaeus*, *C. eos*, or their hybrid.

Five complete *Chrosomus* sp. from the 2012 collection were archived at the Royal Ontario Museum (accession number: ROM 104124). Additionally, 20 caudal fin tissues, used for genetics-based identification, were transferred to The Rooms Corporation of Newfoundland and Labrador, Provincial Museum Division (accession number: NFM T-2018-63). All specimens were preserved in 95% ethanol.

Results

Species account

In 2012, native fish species captured included Brook Trout (*Salvelinus fontinalis*), Atlantic Salmon (*Salmo salar*), and Threespine Stickleback (*Gasterosteus aculeatus*; Table 2). In addition, 14 dace were also sampled from three of the four ponds surveyed (Mina 1, 2, and 4; Table 2). Stomach examinations revealed that one Brook Trout, from Mina 1, contained approximately 20 partially digested young-of-the-year dace (Figure 2a).

In 2014, 527 dace were sampled from all four lakes, for an average capture of 13.5 fish per pot. Figure 2b shows three representative specimens from the collection. In Tributary 2 we did not capture any dace in either Ponds A or B, nor did we sample any dace when electrofishing the lower and upper reaches of Tributary 1. Only native species Brook Trout, American Eel (*Anguilla rostrata*), Atlantic Salmon, and Threespine Stickleback were sampled.

Genetic results

Of the 20 selected samples, 16 yielded sufficient DNA quantity and quality for species identification. The remaining four were excluded due to DNA quality concerns. Our examination of the amplifications of the GH locus showed band size uniformity among all individuals, with a band size of approximately 250 bp. This particular fragment/band size is indicative of *C. neogaeus* (Binet and Angers 2005). A similar result was observed for the PEG1/MEST amplifications: band size uniformity of approximately 177 bp. Again, this particular band size is indicative of *C. neogaeus* (Binet and Angers 2005). There was no

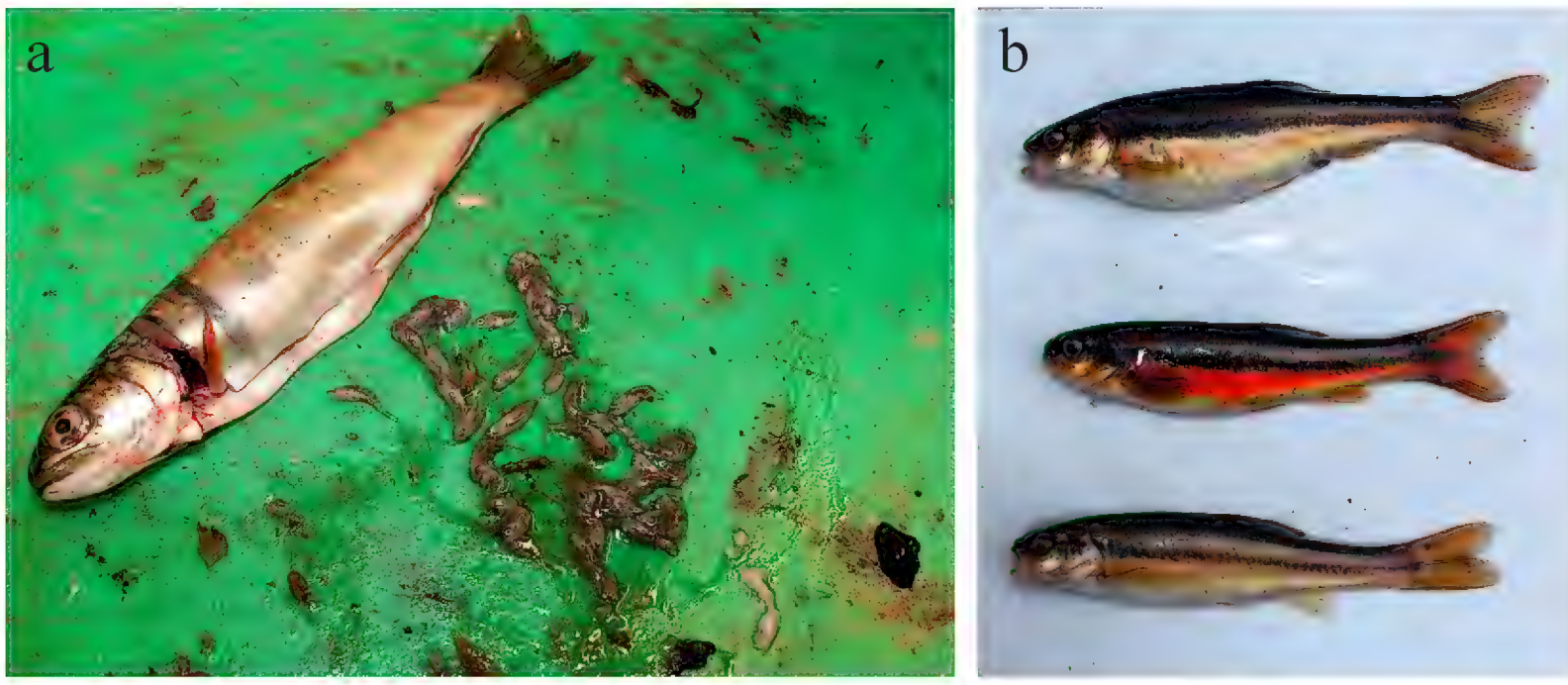

FIGURE 2. a. Stomach contents of a Brook Trout (*Salvelinus fontinalis*) captured in pond Mina 1, central Newfoundland, on 7 June 2012, showing approximately 20 partially decomposed immature cyprinid species. b. Finescale Dace (*Chrosomus neogaeus*) sampled from pond Mina 2, central Newfoundland, on 14 June 2014 Photo: a. Robert Perry. Photo: b. Donald Keefe.

evidence of any other band size or combination in any of the 16 individuals tested at either of these two nuclear DNA loci, indicating the absence of both hybrid *C. eos-neogaeus* and *C. eos* individuals.

Discussion

The record of Finescale Dace in four headwater ponds in the Exploits River watershed represents the first report of an introduced Leuciscinae species for insular Newfoundland. The species complement for the island portion of the province contains only euryhaline (saltwater tolerant) species (Scott and Crossman 1964; van Zyll de Jong *et al.* 2004) and Finescale Dace is not considered euryhaline. Therefore, it is unlikely that the species colonized the area naturally and indicates that an exotic introduction has occurred. The known distribution of Finescale Dace extends across the southern and northwest parts of Canada (Scott and Crossman 1998). In the east, its distribution reaches New Brunswick and Nova Scotia while in the United States it can be found in the Mississippi and Missouri river drainages (Stasiak 1980; Page and Burr 1991). The origin for the Jumpers Brook population is uncertain.

Because young-of-the-year minnows were found during stomach examination of Brook Trout it is evidence that the nonindigenous species is established. The habitat preferences for Finescale Dace include acidic beaver ponds, boggy waters, and small lakes with bottom detritus and silt (Stasiak and Cunnigham 2006). The locations in which we discovered Finescale Dace fit the habitat requirements for the species (Mee and Rowe 2010).

In accordance with our 2014 field sampling, we did not find evidence for the presence of Finescale Dace in either Tributary 1 or in the headwater ponds of Tributary 2. It would appear that the presence of the dace is currently limited to the four headwater ponds of Tributary 1. We believe the containment is owing to the presence of beaver dams in ponds Mina 1 and Mina 2 which limit the outflow of water and impedes fish movement. The outflow from Mina 2 is downstream from Mina 3 and 4 and therefore controls the flow of water from these two ponds.

If the intent of the introduction was to provide a food source for both Brook Trout and juvenile Atlantic Salmon, it may have been short-sighted. Although we did find juvenile dace in the stomach of an adult Brook Trout, it is unclear how additional competition for food sources will affect native fish populations into the future. Finescale Dace are sight feeding, carnivorous predators and have been documented as eating a wide variety of food items including aquatic insects, vegetation, and molluscs (Stasiak and Cunnigham 2006; Mee *et al.* 2013). For example, adult fish have been documented eating midges (Diptera), beetles (Coleoptera), caddisflies (Trichoptera), mayflies (Ephemeroptera), and bugs (Hemiptera; Stasiak 1972). Native species such as Brook Trout, Atlantic Salmon, and Threespine Stickleback depend upon micro and macro invertebrates, particularly at juvenile stages (Scott and Crossman 1998). Further, these types of minnows have a large reproductive capacity. It has been reported that Northern Redbelly Dace can produce 316 000 fish per ha of surface area in a single season (Cooper 1935). Finescale Dace also has a substantial reproductive capability. For example; a 70 mm female may produce 2600 eggs (Stasiak 2011). Given the potential for these types of cyprinids to have a large reproductive capacity, it is probable that the presence of Finescale Dace will lead to interspecific resource competition with native species.

Competition among piscivores and planktivores can have a large influence on rates of primary production in an aquatic ecosystem (Carpenter *et al.* 1985; Carpenter and Kitchell 1988). Following the introduction of Eurasian Minnow (*Phoxinus phoxinus*) into a Norwegian subalpine lake, Øvre Heimdalsvatn, researchers witnessed major changes to both the structure and composition of macroinvertebrate benthos (Naestad and Brittain 2010). These changes led to negative effects on the native Brown Trout population, including reduced annual recruitment and growth rates. Researchers attributed the changes to competition for food (Borgstrom *et al.* 2010).

There may also be a direct effect on native species abundance, as these types of predatory minnows have been documented eating the eggs and young of other species. A dissected large male Finescale Dace was reported having its intestinal tract full of fish eggs (presumed to be the eggs of the Northern Redbelly Dace; Stasiak 1972). Becker (1983) reported that dace will eat guppies in an aquarium setting. Furthermore, it has been reported that Northern Redbelly Dace, a species whose dietary preferences overlap with the Finescale Dace (Cochran *et al.* 1988), would eat Smallmouth Bass (*Micropterus dolomieu*) fry (Scott and Crossman 1999). Thus, it is possible that fry of Brook Trout and stickleback could also provide a food source for Finescale Dace. Further work is required to determine the short and long-term impacts of this introduction on native fauna.

The discovery of Finescale Dace in this particular watershed is disconcerting. The Exploits River represents one of the largest Atlantic Salmon producing rivers in North America (Pinfold 2011). The spread of this stenohaline species throughout the Exploits watershed may be limited by the presence of the Grand Falls Hydro-electric facility. The facility serves as a major barrier to fish passage and is located

just upstream from where the tributary containing dace enters the main branch of the Exploits River.

The origin of Finescale Dace found in the four headwater ponds is uncertain. However, there are two possible explanations. The species current documented range limit in eastern Canada are the provinces of New Brunswick and Nova Scotia (Stasiak 1980; Page and Burr 1991). Therefore, it is possible that anglers imported the species as an illegal form of bait from the Maritime region. However, this explanation seems improbable given that these ponds are small in size and not known as a favoured area for recreational fishing. Another possible explanation may be that minnows kept in aquaria by area residents were released. Local residents interviewed regarding this possibility suggested that an unknown species of minnow had been housed in close proximity to the headwater ponds. Speculation by those interviewed was that minnows were imported from Labrador. Although interesting, this idea is unsubstantiated.

The presence of Finescale Dace in Labrador (even if remote) is an intriguing possibility. The present range distribution for Finescale Dace does not extend into Labrador and the only known species of dace existing in the province is Northern Pearl Dace (*Margariscus nachtriebi*). Thus, one may speculate that an undiscovered species is present or, alternatively, the current identification for the species in Labrador maybe an error. Further genetic work is required to investigate these possibilities.

Our findings suggest these minnow species are readily trapped and therefore could easily be moved as bait to other regions of the province. However, it is illegal in Newfoundland and Labrador to transport live fish or to use live fish as bait in inland waters. It is hoped that these regulatory restrictions will serve as a deterrent to the spread of the species. Additionally, to limit the spread of Finescale Dace, we recommend the launch of a public education and awareness program pertaining to the existence of these species in the province. Such an initiative would be beneficial and low cost for regulatory authorities. Through this effort, it is hoped that further illegal introductions or transfers could be curtailed. Additionally, the four ponds where these dace were found were small and therefore we recommend some consideration should be given to an eradication program to halt their spread.

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Albinism in Orange-footed Sea Cucumber (*Cucumaria frondosa*) in Newfoundland

Emaline M. Montgomery[1,*], Tiffany Small[1], Jean-François Hamel[2], and Annie Mercier[1]

[1]Department of Ocean Sciences, Memorial University, St. John's, Newfoundland and Labrador A1C 5S7 Canada
[2]Society for Exploration and Valuing of the Environment, Portugal Cove-St. Phillips, Newfoundland and Labrador A1M 2B7 Canada
*Corresponding author: e.montgomery@mun.ca

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Abstract

Orange-footed Sea Cucumber (*Cucumaria frondosa*; Echinodermata: Holothuroidea) is a dark-brown species that is broadly distributed in North Atlantic and Arctic waters. Here, we document the rare occurrence of colour morphs showing various degrees of albinism, from totally white to faint orange pigmentation. These unusually coloured individuals were found across a broad distribution range in eastern Canada and northeastern United States, with their occurrence in Newfoundland samples ranging from 0.2% to 0.5%. Two fully albino individuals were noticeably smaller than other colour morphs. The occurrence of rare, unusually coloured sea cucumbers is important from an ecological standpoint and may also have commercial implications.

Key words: Orange-footed Sea Cucumber; *Cucumaria frondosa*; albinism; colour diversity; Holothuroidea; sea cucumber; North Atlantic

Introduction

Unusually coloured and albino (white) sea cucumbers are rare in nature and typically have higher market value, particularly in Asia. Albino individuals have sold at auction for US$23 000/kg (normal value US$2000–2500/kg for the species; Tse 2015). To date, published records of albinism in holothuroid echinoderms (nomenclature according to World Register of Marine Species; WoRMS 2019) include Japanese Sea Cucumber (*Apostichopus japonicus*) in the temperate Western Pacific (Lin *et al.* 2013), White Teatfish (*Holothuria fuscogilva*) in the tropical Indo-Pacific (Friedman and Tekanene 2005), Brown Sea Cucumber (*Isostichopus fuscus*) in the tropical eastern Pacific (Fernández-Rivera Melo *et al.* 2015), Foursided Sea Cucumber (*Isostichopus badionotus*) in the Caribbean (Wakida-Kusunoki *et al.* 2016), Climbing Sea Cucumber (*Ocnus planci*) in the temperate and tropical Atlantic (Casellato *et al.* 2006), along with some anecdotal reports and pictures of white sea cucumbers scattered in the literature (Trefry 2001; Feindel *et al.* 2011; Benoît 2016).

Colour variants, including complete lack of colour, in *A. japonicus* have been described (Yang *et al.* 2015). The body wall of albino *A. japonicus* adults contains ~0.24% melanin compared with ~3.12% in normal adults (Zhao *et al.* 2015). As albinism is known to occur in only a limited number of individuals in any given species (0.00001–0.1%; Mouahid *et al.* 2010), a directed search for these could fuel overexploitation in some already overfished or vulnerable species (Purcell *et al.* 2014). Albinism may also affect the behaviour, growth rates, and physiology of sea cucumbers, although these effects remain incompletely understood (Lin *et al.* 2013; Bai *et al.* 2016; Xia *et al.* 2017).

Orange-footed Sea Cucumber (*Cucumaria frondosa*, Gunnerus 1767) is the most common sea cucumber along the eastern Canadian coast, with a distribution spanning the North Atlantic, Arctic, and Barents Sea (Paulay and Hansson 2013). A commercial fishery for *C. frondosa* is rapidly developing in several countries (e.g., Canada, United States, Russia, Greenland, and Iceland), which makes it one of the most important wild sea cucumber fisheries in the world (Therkildsen and Petersen 2006; Nelson *et al.* 2012). As of 2016, market values for *C. frondosa* ranged from $120–140/kg (Hansen 2016) up to about $300/kg (Guangzhou market, China; J.-F.H. pers. obs.); a separate market for unusual colour morphs has not yet developed.

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Here, we describe colour morphs reported for wild *C. frondosa* populations from northeastern North America. We also report the results of a survey of *C. frondosa* populations from the Grand Banks of Newfoundland to determine the relative abundance of colour morphs to improve ecological knowledge of this important commercial species.

Methods

Records of unusually coloured *C. frondosa* were collated from numerous sources, including specimens collected by hand, SCUBA, and fishing vessels across various locations in eastern Canada (e.g., the estuary and Gulf of St. Lawrence, Quebec; Saint-Pierre Bank and southeastern coast of Newfoundland; Figure 1, Table 1).

Two batches of sea cucumbers ($n = 600$) were examined in June and July 2017 to establish the percentage of orange and white individuals relative to normally coloured ones (dark-brown and grey-brown); no colour standards were used. Samples were obtained from the commercial fishery (trawled using modified scallop gear) in the Grand Banks area of Newfoundland, Canada. No restrictions are placed on animal size, shape, or colour in the fishery; thus, harvests are usually a good representation of local populations. Total wet weights of sea cucumbers, as well as the contracted lengths and widths were measured from fully contracted individuals according to Singh *et al.* (2001). These measurements were taken for all white and orange individuals and from 150 haphazardly selected dark-brown and grey-brown individuals. For white and orange individuals collected in the Grand Banks area of Newfoundland in 2013, two additional measurements were included. Internal organ colours were also compared in pale versus normal individuals.

Results

Summary of colour morphs in northeastern North America

Four main colour variants have been reported for *C. frondosa* in northeastern North America: dark-brown, grey-brown, orange, and albino (i.e., white and off-white individuals; Figure 2). Dark-brown and grey-brown are the most common colours for this species and, thus, represent normally coloured individuals (Figure 2a,b). The tentacles and tube feet of dark-brown and grey-brown *C. frondosa* are dark-brown and dark-orange to brown, respectively. Orange-tinged tube feet are common, hence the common name (Paulay and Hansson 2013). Orange and white individuals are the rarest colour morphs and can be described as a gradient of little to no melanin pigment deposition (Figure 2c–g). The tentacles and tube feet of orange and white individuals are typically pale orange and white, respectively.

Frequency of colour morphs in Newfoundland trawls

All four colour morphs were found off the Grand Banks, Newfoundland (trawled at 40–70 m depth) and in coastal areas near the Avalon Peninsula (collected by SCUBA at <10 m). The survey from the Grand Banks area revealed that orange-coloured individuals made up 0.5% of the population ($n = 3$ in 600), but that white individuals were rarer in that sample ($n = 1$ in 600, <0.2%). The internal organs (muscle bands, gonad, and intestine) of these white and orange individuals were the same colour as those of dark-brown and grey-brown individuals. Orange individuals were also similar in size to brown individuals (mean wet

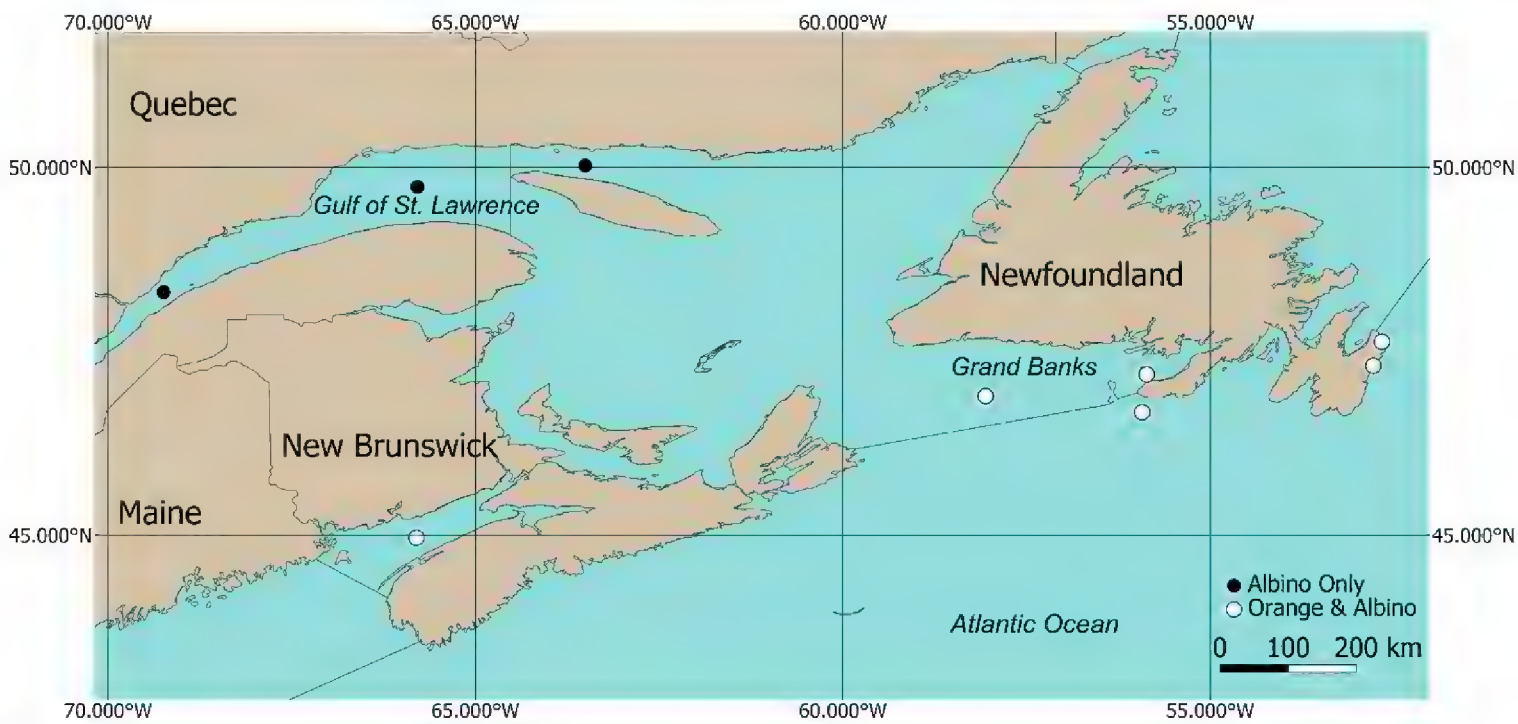

FIGURE 1. Locations in northeastern North America where unusually coloured Orange-footed Sea Cucumbers (*Cucumaria frondosa*) were observed and/or collected.

weight 246 ± 87 [SD] g versus 235 ± 74 g; Table 2). The mean wet weight of the two white individuals, including the one in our 2017 survey and another from 2013 (B. Gianasi pers. comm. October 2017), was 78.6 ± 3.4 g (versus mean wet weight of 235 g in normally coloured individuals; Table 2).

TABLE 1. Locations in North America where unusually coloured Orange-footed Sea Cucumber (*Cucumaria frondosa*) occur, based on reports from the literature and the present study.

Province or state, country	Region	Coordinates	Colour observed	No. (total sampled)	Date	Source
Maine, USA	NA	NA	Orange	NA	NA	Feindel *et al.* 2011
	NA	NA	Albino	NA	NA	Feindel *et al.* 2011
Newfoundland, Canada	Fortune Bay, Grand Banks	47.18597933°N, 55.86135864°W	Orange	3 (600)	2017	E. Montgomery (current study)
		47.18597933°N, 55.86135864°W	Albino	1 (NA)	2017	E. Montgomery (current study)
	St. Pierre Bank, Grand Banks	46.67205647°N, 55.92315674°W	Orange	3 (NA)	2017	E. Montgomery (current study)
		46.67205647°N, 55.92315674°W	Albino	NA	2017	E. Montgomery (current study)
	Unnamed site, Grand Banks	46.89023157°N, 58.05450439°W	Orange	3 (NA)	2013	B. Gianasi (current study)
		46.89023157°N, 58.05450439°W	Albino	1 (NA)	2013	B. Gianasi (current study)
	Logy Bay	47.6295369°N, 52.66073227°W	Orange	NA	NA	Memorial Field Services
		47.6295369°N, 52.66073227°W	Albino	NA	NA	Memorial Field Services
	Bay Bulls	47.3048439°N, 52.77677536°W	Orange	NA	NA	Memorial Field Services
		47.3048439°N, 52.77677536°W	Albino	NA	NA	Memorial Field Services
Quebec, Canada	Mingan Archipelago	50.02538762°N, 63.50372314°W	Albino	NA	1990s	J.-F. Hamel
	Gaspé Peninsula	49.73513141°N, 65.78887939°W	Albino	NA	1990s	J.-F. Hamel
	Les Escoumins	48.30512072°N, 69.24407958°W	Albino	NA	1990s	J.-F. Hamel
New Brunswick, Canada	Bay of Fundy	44.96479793°N, 65.80261230°W	Orange	NA	NA	S. Robinson (DFO)
		44.96479793°N, 65.80261230°W	Albino	NA	NA	S. Robinson (DFO)

Note: DFO = Department of Fisheries and Oceans, NA = data not available.

FIGURE 2. Colour diversity in adults of Orange-footed Sea Cucumber (*Cucumaria frondosa*) collected off Newfoundland, eastern Canada. a and b. Typical colours: dark-brown and grey-brown. c to g. Increasing discolouration/albinism: pale brown, orange, pale orange, beige, and white. Sea cucumbers that match c, d, or e are considered "orange", and those like f and g are considered "white". Photos were taken with uniform illumination and have not been edited for brightness, contrast, or colour. Scale bar represents 5 cm for a–f and 3 cm for g. Photos: E. Montgomery.

TABLE 2. Size of individuals of Orange-footed Sea Cucumber (*Cucumaria frondosa*) sampled in southeastern Newfoundland during the present study. Mean values for orange and white colour morphs are pooled across individuals collected in this area, 2013–2017. Mean values for fully pigmented morphs were obtained from individuals collected in 2017.

Colour morph	*n*	Mean weight, g ± SD	Mean contracted length, cm ± SD
White (fully albino)	2	78.7 ± 3.4	8.2 ± 1.5
Orange (partly albino)	9	246.3 ± 87.1	12.7 ± 1.9
Dark-brown/ grey-brown (fully pigmented)	150	235.1 ± 74.0	13.3 ± 0.5

Discussion

Four main colour morphs of the body wall have been reported for *C. frondosa* from northeastern North America. However, it is important to note that a continuum of degree of pigmentation exists in this species, ranging from dark-brown to white. White and orange individuals from Newfoundland had normally coloured internal structures and organs, suggesting that this species may display leucism (partial or complete loss of pigment), rather than true albinism (no pigment deposition). In fact, some of the dark individuals housed in the laboratory for several months displayed a tendency to bleach over time (B. Gianasi pers. comm. 2017).

In the present study, white and orange individuals were seen and collected in all known populations of *C. frondosa* sampled in eastern Canada, suggesting that loss or decrease of pigmentation is not geographically constrained. An anecdotal reference to unusually coloured individuals is also made in a fisheries report from Maine (Feindel *et al.* 2011), further supporting the suggestion that the phenomenon likely occurs across populations of *C. frondosa* in North America, northern Europe, and the Arctic, as a gene flow study of So *et al.* (2011) indicates a supply source along southeastern Newfoundland. Further study will be needed to confirm the factors involved in pigment absence and/or loss in this species, as the phenomenon seems to be geographically widespread.

We noted that different colour morphs of *C. frondosa* were collected in Newfoundland from different depths. Dark-brown sea cucumbers occurred in shallow water <10 m deep (collected by SCUBA) and grey-brown individuals in deeper water (40–70 m; collected by trawl) where less ultraviolet (UV) light penetrates, and weaker pigment protection may be required, as also proposed for *A. japonicus* (Jiang *et al.* 2015). Also of note is the fact that white individuals were present in all sampled locations, mixed with the normally coloured morphs (Figure 1). Despite this, it remains possible that these individuals may be more susceptible to UV light than normally coloured individuals and may seek cover more readily than darker individuals. In the lower subtidal area of the St. Lawrence Estuary and the Mingan Archipelago of Quebec, pale individuals were reported mainly from discrete areas at the base of rocks or under dense algal cover (J.-F.H. pers. obs.), suggesting that they are actively seeking shelter against exposure to strong light, similar to increased covering behaviour reported in albino urchins in the Caribbean (Kehas *et al.* 2005).

Paler sea cucumbers reported from the Bay of Fundy, New Brunswick, did not appear to differ in size from dark-brown and brown individuals (S. Robinson pers. comm. October 2017), which is consistent with the current samples. Although any size difference remains to be confirmed with further sampling, white sea cucumbers stand out against the background substrate colour, which may generate more stress and, together with decreased UV protection, might explain why they would be generally smaller than normally coloured individuals (Table 2). Their relatively smaller size may also be explained by metabolic factors, as white sea cucumbers have previously been reported as less efficient at protein metabolism than other colour morphs (e.g., *A. japonicus*, Bai *et al.* 2016).

Our data document the presence of uncommon colour morphs of *C. frondosa* across most of its eastern Canadian distribution (Figure 1) and other areas from its general geographic distribution. This deserves further investigation from both ecological and economical perspectives.

Author Contributions

Writing – Original Draft: E.M. and T.S.; Writing – Review & Editing: E.M., T.S., J.-F. H., and A.M. Investigation: E.M., T.S., J.-F. H., and A.M.; Formal Analysis: E.M. and T.S.; Funding Acquisition: A.M.

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Wintercresses (*Barbarea* W.T. Aiton, Brassicaceae) of the Canadian Maritimes

Colin J. Chapman[1,*], C. Sean Blaney[1], and David M. Mazerolle[1,2]

[1]Atlantic Canada Conservation Data Centre, P.O. Box 6416, Sackville, New Brunswick E4L 1G6 Canada
[2]Current address: Kouchibouguac National Park, 186 Route 117, Kouchibougouac, New Brunswick E4X 2P1 Canada
*Corresponding author: colin.chapman@accdc.ca

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Abstract

We conducted a review of herbarium collections of the Wintercress genus (*Barbarea* W.T. Aiton) from the Maritime provinces. Most specimens previously determined to be the regionally rare native species Erect-fruit Wintercress (*Barbarea orthoceras* Ledebour) are in fact the uncommon exotic Small-flowered Wintercress (*Barbarea stricta* Andrzejowski). The latter species is here reported as new to Atlantic Canada, where it is scattered but widespread in the three Maritime provinces. Only three collections (two from New Brunswick and one from Nova Scotia) were confirmed as *B. orthoceras*. Its known range extent and area of occupancy in the Maritimes has been significantly revised, and *B. orthoceras* is now considered potentially extirpated in New Brunswick and extremely rare in Nova Scotia. One collection from Nova Scotia was referred to another rare exotic species, Early Wintercress (*Barbarea verna* (Miller) Ascherson), which represents the first record for the Maritimes.

Key words: Cruciferae; Brassicaceae; new record; floristics; *Barbarea stricta*; *Barbarea orthoceras*; *Barbarea verna*; conservation; Maritimes; Canada; wintercress

Introduction

The wintercress genus (*Barbarea* W.T. Aiton) has long been a source of confusion in North America, in part due to taxonomy and to somewhat variable species with overlapping morphology (Fernald 1909; Mulligan 2002; Al-Shehbaz 2010). The sole native North American member of the genus, Erect-fruit Wintercress (*Barbarea orthoceras* Ledebour), was at one point considered a native form of the Eurasian species Bitter Wintercress (*Barbarea vulgaris* W.T. Aiton) or Small-flowered Wintercress (*Barbarea stricta* Andrzejowski; discussed in Fernald 1909). Fernald (1909), who concluded reports of *B. stricta* were misidentified individuals of *B. vulgaris* with appressed fruit, excluded the former species from the North American flora. Mulligan (1978) reported the first confirmed North American records of *B. stricta* based on specimens collected from Quebec in 1944, although the species was not included in *The Flora of Canada* (Scoggan 1978). *Barbarea stricta* has subsequently been documented in Ontario (based on a 1922 specimen; Dorofeev 1998), Colorado, Connecticut, Maine, Michigan, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, and Wisconsin (Al-Shehbaz 2010). Prior to our study, only two species of *Barbarea* were listed in the flora of the Canadian Maritimes (New Brunswick [NB], Nova Scotia [NS], and Prince Edward Island [PEI]): *B. vulgaris* and *B. orthoceras* (Roland and Smith 1969; Scoggan 1978; Zinck 1998; Hinds 2000; Munro *et al.* 2014).

Barbarea vulgaris is a common and widespread weedy species of Eurasian origin, well documented from throughout NB, NS, and PEI (Erskine 1960; Roland and Smith 1969; Zinck 1998; Hinds 2000; AC CDC 2019; Figure 1). *Barbarea orthoceras* is native to boreal North America and eastern and central Asia (Al-Shehbaz 2010). Haines (2011) considers *B. orthoceras* a calciphile associated in New England with high-pH bedrock or till, although a variety of habitats, including grasslands, forests, boggy ground, and railroad embankments are reportedly suitable (Al-Shehbaz 2010). Though relatively secure in the western and northern portion of its range, *B. orthoceras* is rare in eastern North America and is of conservation concern in all jurisdictions of occurrence east of Ontario (NatureServe 2017). As of 2000, it was reported in the Maritimes from five NB locations on "stream banks, sandy beaches, gravel river strands, and rocky shores" (Hinds 2000: 225). An additional nine NB collections and two NS col-

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lections initially identified as *B. orthoceras* were deposited at regional herbaria between 2001 and 2015 (AC CDC 2019; Figure 2), but in 2015 D.M.M. suspected some Maritimes records involved *B. stricta*, so we undertook a thorough specimen review to determine the regional status of *B. orthoceras*, *B. stricta*, and *B. vulgaris*.

Methods

Approximately 170 specimens from four regional herbaria (E.C. Smith Herbarium—Acadia University [ACAD], New Brunswick Museum [NBM], Nova Scotia Museum of Natural History [NSPM], Connell Memorial Herbarium—University of New Brunswick [UNB]) and one national herbarium (Canadian Museum of Nature [CAN]) were examined by C.J.C. in 2018. Specimens from Agriculture and Agri-Food Canada's National Collection of Vascular Plants [DAO] were unavailable for examination due to facility renovations. Plants were determined based on the treatments in Al-Shehbaz (2010) and Haines (2011). A simplified key is presented here:

1a. Stylar beaks narrow, longer than 1.5 mm (Figure S1); auricles of distal leaves glabrous..... ..... *B. vulgaris*

1b. Stylar beaks stout, less than 1.5 mm long (Figure S2); auricles of distal leaves at least sparsely ciliate 2

2a. Uppermost leaves dentate (Figure S3); petals less than 4.5 mm long (Figure S4); fruit mostly shorter than 28 mm long..... *B. stricta*

2b. Uppermost leaves pinnatifid (Figure S5); petals greater than 5 mm long; fruit mostly greater than 31 mm long..... 3

3a. Basal leaves with 1–4 pairs lateral lobes; fruit usually under 40 mm long; fruiting pedicels narrower than fruit ..... *B. orthoceras*

3b. Basal leaves with 4–10 pairs lateral lobes; fruit usually greater than 53 mm long; fruiting pedicels as broad as fruit ..... *B. verna*

Clear determinations could be made for most specimens, but some collections presented conflicting morphology, as is mentioned of NB (Hinds 2000), New England (Al-Shehbaz 2010), and Michigan (Voss

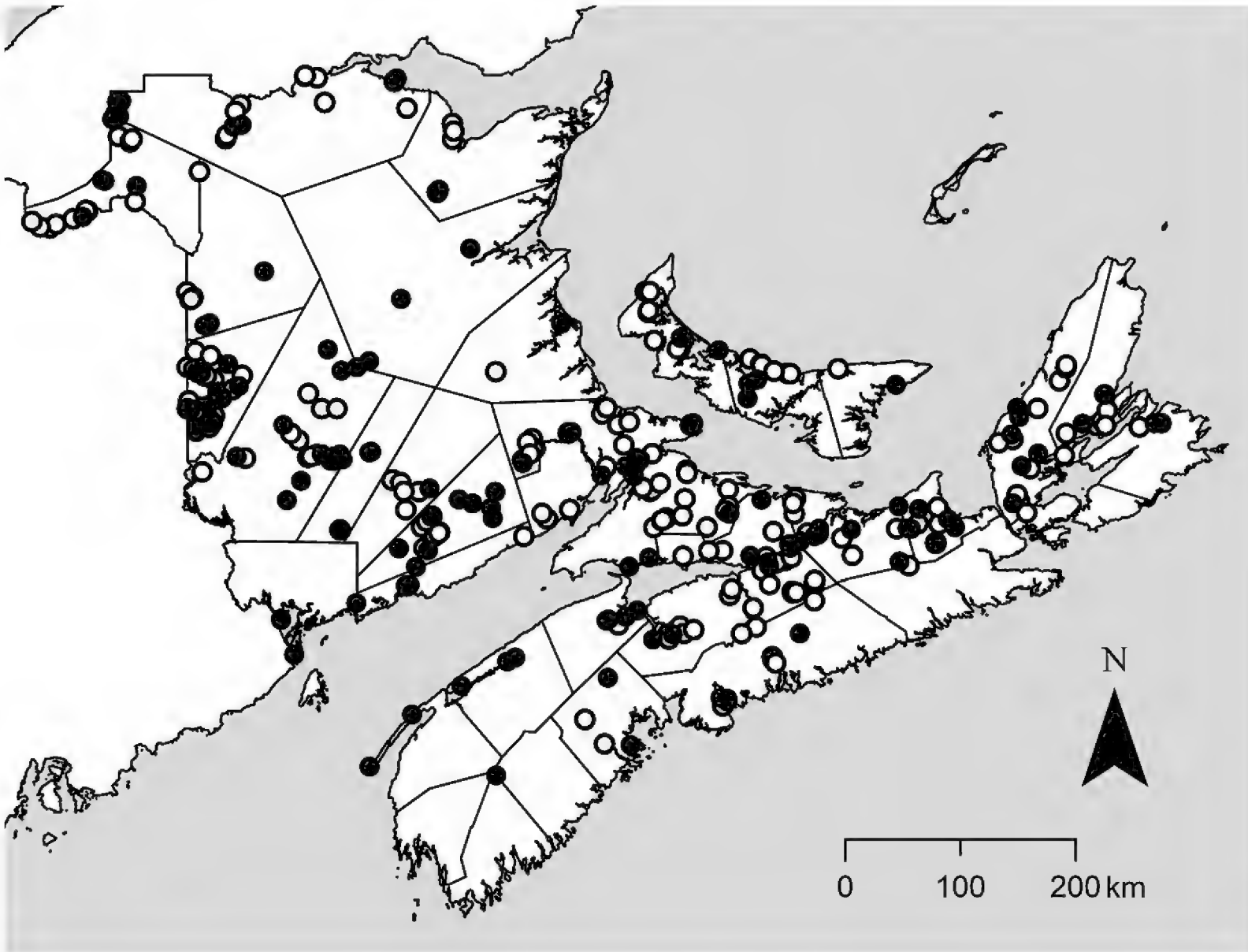

FIGURE 1. Distribution of Bitter Wintercress (*Barbarea vulgaris*) in the Canadian Maritimes based on specimens (solid circles) and Atlantic Canada Conservation Data Centre sight records (hollow circles) determined and verified during the present study.

and Reznicek 2012) material. We sent a small subset of six specimens to Ihsan Al-Shehbaz, Missouri Botanical Garden, and he confirmed all six as the species initially determined by C.J.C.

All records in this paper are either supported by voucher specimens or are photographic or sight records made by Atlantic Canada Conservation Data Centre (AC CDC) botanists.

Results and Discussion

Barbarea vulgaris W.T. Aiton

Barbarea vulgaris remains the most frequently encountered and widespread species of *Barbarea* in the Maritimes (Figure 1). As a weedy species, *B. vulgaris* is found in a variety of anthropogenic habitats such as fields and roadsides (Erskine 1960; Roland and Smith 1969; Hinds 2000). It is also frequent on river shores, where it can co-occur with *B. stricta* and potentially with *B. orthoceras*. The taxon is morphologically variable, and though many varieties have been described (treated in Fernald 1909), none are presently recognized in North America (Al-Shehbaz 2010). Some specimens present mixed or intermediate morphology in style length, uppermost leaf shape, and auricle pubescence. Hinds (2000) reported apparently intermediate NB specimens and suspected hybridization might be involved. Hybrids of *B. vulgaris* and *B. stricta* (= *B.* × *schulzeana* Haussknecht) are recorded for Europe, although occurrences are very infrequently recorded and highly sterile (Rich 1987). If hybrids were also sterile in the Maritimes, we might expect a lower frequency of plants intermediate between *B. vulgaris* and *B. orthoceras* than has been observed. These intermediates may thus be morphological extremes of the highly variable *B. vulgaris*.

Barbarea orthoceras Ledebour

We found that only one specimen initially identified as *B. orthoceras* was determined correctly. The remainder were reassigned to *B. stricta* or in very few cases *B. vulgaris*. An additional *B. orthoceras* record was discovered upon redetermination of a specimen originally identified as *B. vulgaris*. The two specimens now confirmed for NB were collected in 1944 along water-runs in an old pasture on Grand Manan Island (*C.A. Weatherby & Una F. Weatherby 7343*), and in 1964 on a roadside at the edge of a Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) forest in Kings County (*P.R. Roberts*

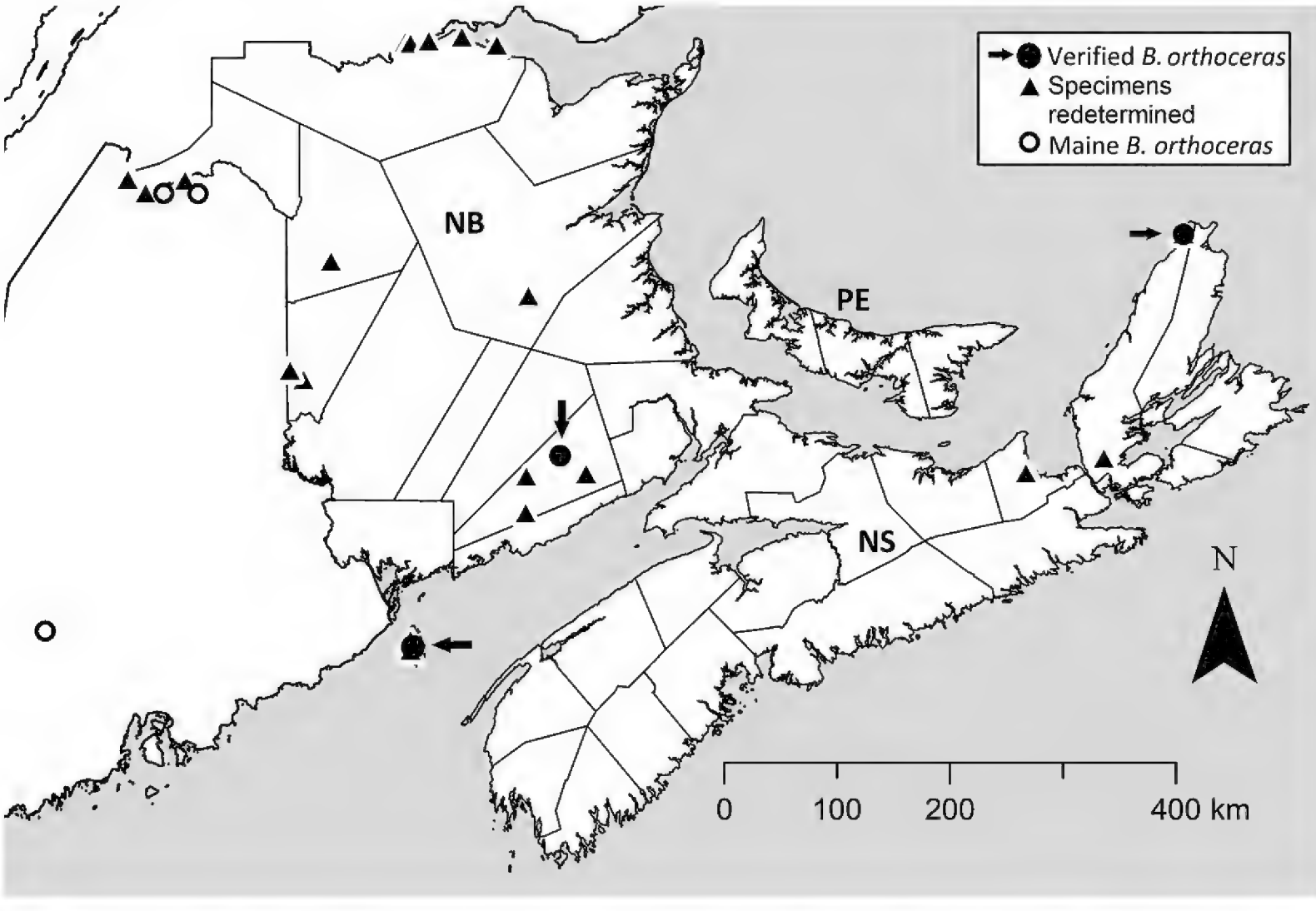

FIGURE 2. Distribution of the rare native Erect-fruit Wintercress (*Barbarea orthoceras*) in New Brunswick (NB), Nova Scotia (NS), and Prince Edward Island (PE) based on specimens determined and verified during the present study. Historical records from Maine provided by the Maine Natural Heritage Program were not verified, but one Maine collection at the New Brunswick Museum was redetermined as *B. orthoceras*.

& N. Bateman 64-361). C.S.B. discovered the first and only known NS population on a steep, seepy ravine slope under shrubs in northern Cape Breton in 2016 (collection number *8978*).

Barbarea orthoceras was first reported for NB based on two specimens revised by H.J. Scoggan in 1955 (*R. Chalmers 305a* [now determined as *B. stricta*] and *C.A. Weatherby and Una F. Weatherby 7343*). Scoggan appears unlikely to have considered *B. stricta* as a possible identity because it was not confirmed in North America until much later (Mulligan 1978). Indeed, his key in Scoggan (1978) describes the petals in *B. orthoceras* as "at most 5 mm long", a key character of *B. stricta* (Al-Shehbaz 2010). Hinds (2000) similarly described the petals of *B. orthoceras* as "less than 5 mm long". In fact, the petals are 5–7 mm long in *B. orthoceras*, which is the most reliable character separating it from *B. stricta* (I. Al-Shehbaz pers. comm. 8 May 2018).

One historical collection of *B. orthoceras* (initially misidentified as *B. vulgaris* and later as *B. stricta*) was uncovered from Fort Kent, Maine (*G.U. Hay, s.n.*), along the Saint John River across from Madawaska County, NB. The species is known from two additional historical records in northern Maine, however all recent collections of potential *B. orthoceras* in the state have turned out to be *B. stricta* (L. St. Hilaire and D. Cameron pers. comm. 20 February 2019). All recent records from extensive AC CDC fieldwork along northern NB rivers have also been *B. stricta*, suggesting that, if *B. orthoceras* is present on rivers in the region, it is quite rare. However, the now-confirmed records of *B. orthoceras* from pasture and roadsides in NB suggest it could be overlooked in disturbed sites because of assumptions that *Barbarea* in ruderal habitats must be *B. vulgaris* or *B. stricta*, and because botanists tend to spend less time in ruderal habitats.

Speculation aside, our study greatly decreases the known range extent and area of occupancy for *B. orthoceras* in the Maritime provinces (Figure 2). No recent records exist in NB, where its provincial status has been changed from imperilled/vulnerable (S2S3) to possibly extirpated (SH). It has been confirmed as extremely rare in NS and remains unknown on PEI.

Barbarea stricta Andrzejowski

This study confirmed the presence of *B. stricta* in Atlantic Canada, where it is scattered but widely distributed in NB, NS, and PEI (Figure 3). Haines (2011) and Cayouette (1984) describe *B. stricta* as having invaded river shores, lake shores, and wet, disturbed areas in New England, and Quebec respectively, and it has mostly been collected from similar habitats in the Maritimes. Many *B. stricta* specimens examined in this study had morphology that was at the larger extremes for the species (as also reported in Al-Shehbaz 2010), which is potentially suggestive of genetic influence from the larger *B. orthoceras*. The morphology of these plants might also be explained by the founder principle (Mayr 1942) if North American populations happened to have been founded by unusually large individuals. The morphological similarity of *B. orthoceras* and *B. stricta* would make hybridization difficult to demonstrate without molecular investigation.

We failed to locate historical specimens of *B. stricta* in NS or PEI, suggesting it may have dispersed more recently to these provinces. However, it was introduced in NB as early as 1877 (*R. Chalmers 305a*; now the earliest Canadian record), where collections were misidentified as *B. orthoceras*, or more rarely as *B. vulgaris*. Early introduction of *B. stricta* and overlapping habitat requirements of *Barbarea* species suggests ample opportunity for hybridization in NB. However, because Hinds (2000) appears not to have considered *B. stricta* as a possibility in identifying NB material, his specimens of "intermediate morphology" between *B. vulgaris* and *B. orthoceras* may simply have represented *B. stricta*.

Barbarea verna (Miller) Ascherson

We referred one collection from Kentville, NS (*J.S. Erskine s.n.*) to Early Wintercress (*Barbarea verna* (Miller) Ascherson). Originally identified as *B. vulgaris*, it was distinguished by its leaves with five to seven pairs of lateral lobes, pinnatifid uppermost leaves, and conspicuously ciliate leaf auricles (Al-Shehbaz 2010; Haines 2011). In fruit, *B. verna* can also be distinguished by its large fruit (5.3–7 cm), and pedicels as broad as the fruit they subtend (Al-Shehbaz 2010). This European species is cultivated as a salad plant in North America, where it escapes to disturbed habitats such as fields and meadows (Mulligan 2002; Haines 2011). This represents the first Maritimes record of this rarely reported introduction, otherwise known in Canada only from Newfoundland and British Columbia (Brouillet *et al.* 2010+).

Voucher specimens

Barbarea orthoceras Ledebour—NEW BRUNSWICK: Charlotte Co., Grand Manan, Between Long Pond & Red Pt., weed along water-runs in old pasture, 6 August 1944, *C.A. Weatherby and U.F. Weatherby 7343* (CAN); Kings Co., Lower Millstream, roadside at Black Spruce forest edge, 28 May 1964, *P.R. Roberts & N. Bateman 64-361* (UNB); NOVA SCOTIA: Inverness Co., Pleasant Bay, Lower Delaneys Brook, 46.966519°N, 60.654339°W, steep, seepy ravine slope under shrubs, not seen elsewhere between High Capes & Delaneys Point, with Red-osier Dogwood (*Cornus sericea* L.), Tall Meadow-rue (*Thalictrum pubescens* Pursh), 14 July 2016, *C.S. Blaney 8978* (NSPM);

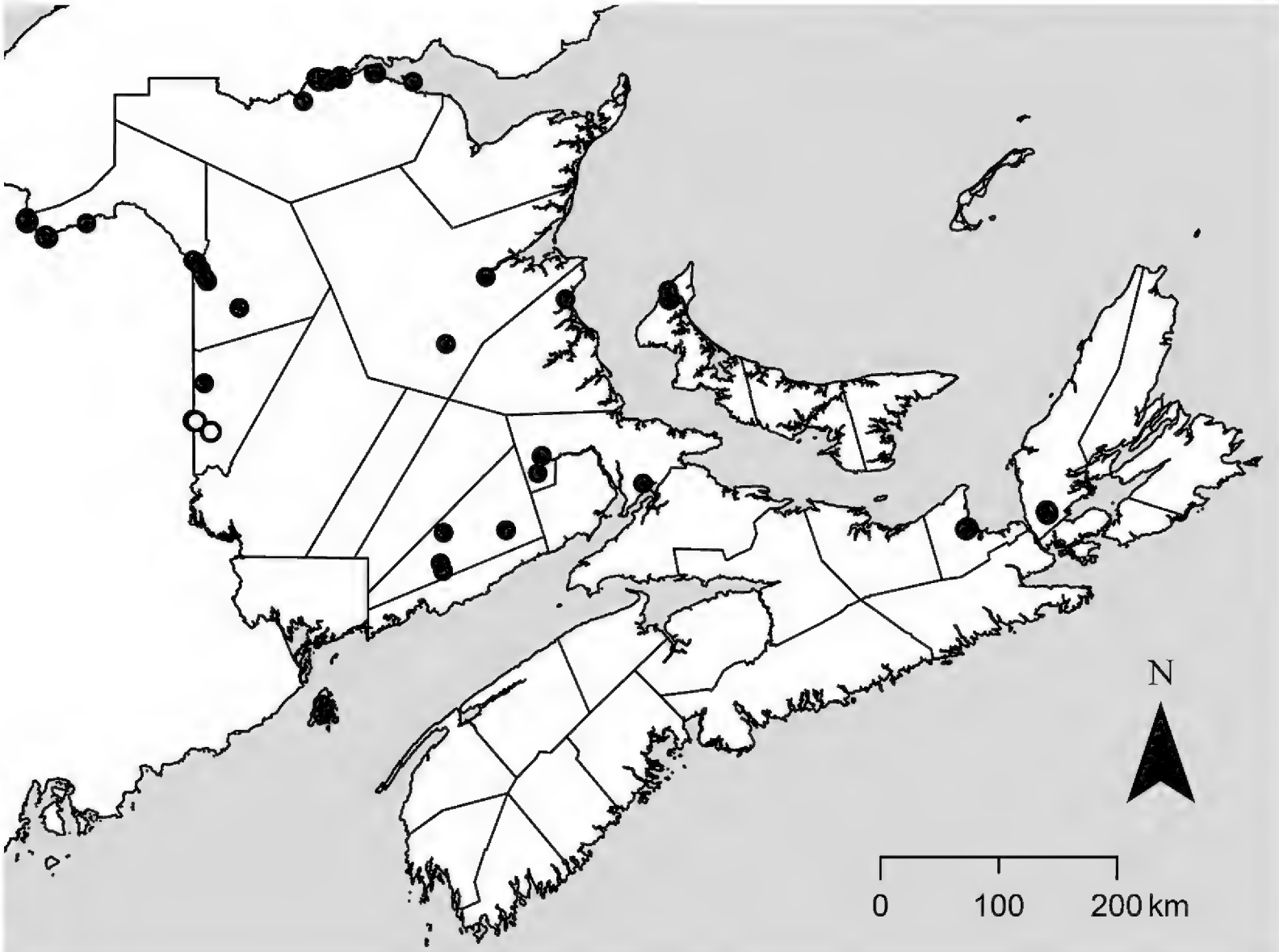

FIGURE 3. Distribution of the uncommon exotic species Small-flowered Wintercress (*Barbarea stricta*) in the Canadian Maritimes based on specimens (solid circles) and Atlantic Canada Conservation Data Centre photographic or sight records (hollow circles; the western sample is shown in Figure S3) determined, verified, or revised during the present study.

MAINE: Aroostook Co., Fort Kent, 8 July 1904, *G.U. Hay s.n.* (NBM).

Barbarea stricta Andrzejowski—NEW BRUNSWICK: Madawaska Co., St. Francis River, 47.182855°N, 68.896639°W, wet mud, in grassy meadow along shore of floodplain island, 11 July 2013, *D.M. Mazerolle DM4032* (NBM, UNB, DAO); Madawaska Co., St. Francis River, 47.285603°N, 69.050753°W, sandy riverbank with sparse alders, 9 July 2013, *C.S. Blaney & D.M. Mazerolle 8267* (NBM); Madawaska Co., St. Francis River, 47.276528°N, 69.049497°W, sandy-bouldery shore under Eastern White Cedar (*Thuja occidentalis* L.), 9 July 2013, *C.S. Blaney 8268* (NBM); Madawaska Co., St. Francis River, 47.26046°N, 69.050219°W, silty sand-gravel rivershore, 9 July 2013, C.S. Blaney 8270 (NBM); Restigouche Co., Campbellton, 20 July 1877, *R. Chalmers 305a* (CAN); Victoria Co., Grand Falls, 47.05527°N, 67.759561°W, 31 July 2018, *D.M. Mazerolle DM7808* (NBM); Restigouche Co., Heron Island, 47.9823°N, 66.11649°W, sandy hummocks, 29 September 1982, *H.R. Hinds 5798* (UNB); Restigouche Co., Eel River, 48.02520°N, 66.39349°W, gravel shore, 5 August 1982, *H.R. Hinds 5400* (UNB); Restigouche Co., Morrissey Rock, 47.983327°N, 66.832622°W, alongside railway tracks, 10 August 1965, *P.R. Roberts & B. Pugh 65-5384* (UNB); Restigouche Co., Restigouche River, 47.990321°N, 66.769302°W, sandy floodplain terrace above river bank, on island in upper estuary near head of tide, 18 September 2013, *D.M. Mazerolle DM4143* (NBM); Restigouche Co., Tidehead, 47.985532°N, 66.767721°W, silty bar in fresh tidal zone, 18 September 2013, *C.S. Blaney 8485* (NBM); Restigouche Co., Eel River, 48.023715°N, 66.412898°W, graminoid floodplain meadow on elevated terrace along brackish tidal river, 26 August 2015, *D.M. Mazerolle DM6967* (NBM, UNB); Restigouche Co., Upsalquitch River, 47.883333°N, 66.951000°W, 12 July 1957, *E.C. Smith 16312* (ACAD); Victoria Co., Arthurette, 46.81718°N, 67.43563°W, gravelly north shore, 27 July 1982, *H.R. Hinds 5361* (UNB); Victoria Co., Grand Falls, 47.059342°N, 67.778800°W, 31 July 2018, *C.J. Chapman 1152* (NBM); Victoria Co.,

Grand Falls, 47.064978°N, 67.788144°W, 31 July 2018, *C.J. Chapman 1158* (UNB); Northumberland Co., Upper Blackville Bridge, 46.629606°N, 65.865519°W, eroding sandy-gravel shore slope, 14 August 2007, *C.S. Blaney & D. Whittam 6646* (UNB); Northumberland Co., Beaubears Island, Miramichi, 46.978856°N, 65.561207°W, On open backshore of east point of island, 7 September 2005, *D. McLeod & C. Merrithew 5271* (UNB); Carleton Co., Big Presque Isle Stream, 46.424062°N, 67.703127°W, moist depression in densely vegetated weedy Balsam Poplar (*Populus balsamifera* L.)/Black Ash (*Fraxinus nigra* Marshall) floodplain, 7 July 2015, *D.M. Mazerolle DM6711* (NBM, UNB); Kent Co., Kouchibouguac NP, 46.86312°N, 64.95513°W, garbage dump, 11 June 1977, *B. Lyons & D. LaFontaine 564* (UNB, ACAD); Kings Co., Hatfield Point, 45.63523°N, 65.88335°W, rocky and gravelly shore, 28 June 1980, *H.R. Hinds 3234* (UNB); Kings Co., Hammond River, 45.471532°N, 65.9056750°W, rich soil in understorey of Silver Maple (*Acer saccharinum* L.) floodplain forest, on floodplain island, 23 August 2017, *D.M. Mazerolle DM7598* (NBM); Westmorland Co., North River, 46.038486°N, 65.138669°W, rich, silty upper river bank, 19 July 2017, *C.S. Blaney 9148* (NBM); Westmorland Co., North River, 46.041878°N, 65.135242°W, silty river bank, 19 July 2017, *C.S. Blaney 9153* (NBM); Westmorland Co., Petitcodiac River, 45.949465°N, 65.166692°W, muddy gravel river bar, 8 September 2017, *C.S. Blaney 9198* (NBM); NOVA SCOTIA: Antigonish Co., Antigonish Harbour, 45.659103°N, 61.895856°W, open, cattle-grazed White Spruce (*Picea glauca* (Moench) Voss) forest on gypsum at edge of saltmarsh, 30 June 2014, *C.S. Blaney 8575* (ACAD); Antigonish Co., Antigonish Harbour, 45.658474°N, 61.899508°W, muddy edge of brackish marsh, 30 June 2014, *C.S. Blaney 8578* (ACAD, NSPM, DAO, UNB); Inverness Co., Glenora, 45.742390°N, 61.293412°W, edge of rich shrubby floodplain terrace, 31 July 2015, *D.M. Mazerolle DM6879* (ACAD, NSPM, DAO); PRINCE EDWARD ISLAND: Prince Co., Miminegash River, 46.860973°N, 64.169513°W, forb and graminoid floodplain meadow, 28 July 2017, *D.M. Mazerolle DM7483* (ACAD, DAO).

Barbarea verna (Miller) Ascherson—NOVA SCOTIA: Kings Co., Kentville, sandy grassy slope, 22 May 1950, *J.S. Erskine s.n.* (NSPM).

Author Contributions

Writing—Original Draft: C.J.C.; Writing—Review & Editing: C.S.B., D.M.M., and C.J.C.; Conceptualization: C.S.B. and D.M.M.; Investigation: C.J.C.; Methodology: C.J.C.; Funding Acquisition: C.S.B., D.M.M., and C.J.C.

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SUPPLEMENTARY MATERIAL:

FIGURE S1. Bitter Wintercress (*Barbarea vulgaris*), with characteristic slender, relatively long stylar beaks (>1.5 mm long).

FIGURE S2. Small-flowered Wintercress (*Barbarea stricta*), with short and stout stylar beaks (<1.5 mm long) and appressed siliques.

FIGURE S3. Small-flowered Wintercress (*Barbarea stricta*), with dentate upper stem leaves and ciliate auricles.

FIGURE S4. Small-flowered Wintercress (*Barbarea stricta*), with relatively short petals (<4.5 mm long).

FIGURE S5. Large-fruit Wintercress (*Barbarea orthoceras*), with pinnatifid uppermost stem leaves. Specimen: National Herbarium of Canada, Canadian Museum of Nature (CAN 60422).

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Note

Summer movements of a radio-tagged Hoary Bat (*Lasiurus cinereus*) captured in southwestern Ontario

Derek Morningstar[1,*] and Al Sandilands[2]

[1]Myotistar, 51 Silverthorne Drive, Cambridge, Ontario N3C 0B4 Canada
[2]1356 Lockie Road, Branchton, Ontario N0B 1L0 Canada
*Corresponding author: myotistar@gmail.com

Morningstar, D., and A. Sandilands. 2019. Summer movements of a radio-tagged Hoary Bat (*Lasiurus cinereus*) captured in southwestern Ontario. Canadian Field-Naturalist 133(2): 125–129. https://doi.org/10.22621/cfn.v133i2.2148

Abstract

Hoary Bat (*Lasiurus cinereus*) is a migratory species known to travel long distances during migration. Little is known about its movement patterns during other periods. An adult male Hoary Bat that we radio-tagged in southwestern Ontario in summer was tracked using the Motus Wildlife Tracking System. It travelled a minimum of 827 km in a circular route over a 2-week period and was last recorded 46 km from the original capture site. Hoary Bat is highly vulnerable to being killed at wind turbines and its propensity to travel great distances during summer and migration may exacerbate the impacts of wind farms.

Key words: Hoary Bat; *Lasiurus cinereus*; summer movement; Motus; radio-tracking; southwestern Ontario

Hoary Bat (*Lasiurus cinereus*) is widely distributed throughout the Western Hemisphere, and may be common in the Great Lakes Region. However, it is among the least frequently encountered species in studies of regional bat communities (e.g., Jung *et al.* 1999).

Hoary Bat travels long distances through its life cycle (Cryan *et al.* 2014). Migratory movements of this species have mostly been inferred from the seasonal distribution of museum specimens (Cryan 2003; Cryan *et al.* 2014), but there are several biases in these data. Kurta (2010) demonstrated that studies based on museum specimens did not match actual distribution and sex ratios of Hoary Bats captured by mist-netting in Michigan. This species is frequently studied through acoustic inventories (e.g., Barclay *et al.* 1999) and mortality studies at wind power facilities (e.g., Kunz *et al.* 2007). Such studies provide no information on individual movement patterns, which can only be determined through physical handling and tracking of individuals. Only one study has documented the long-distance movements of Hoary Bats in North America (Weller *et al.* 2016), and it was conducted in autumn rather than summer.

The non-migratory movements of males have not been well documented. Banfield (1974) stated that males seem to wander erratically during spring and summer and do not associate with females while the latter are caring for their young. Here we provide data on the short-term movements of a radio-tracked male Hoary Bat during mid-summer.

On 9 July 2016, we captured an adult male Hoary Bat in a 12-m triple high mist net near a Little Brown Myotis (*Myotis lucifugus*) maternal roost near Branchton, Ontario (43.2986°N, 80.2900°W). The Hoary Bat was 29.2 g at the time of capture and had a forearm length of 51 mm. A Nanotag radio transmitter (Lotek, Newmarket, Ontario, Canada) was affixed to the back of the bat by shaving a small area and applying a small amount of Osto-Bond (Montreal Ostomy Inc., Vaudreuil-Dorion, Quebec, Canada) glue to the bat and the tag. The mass of the tag reported by the manufacturer was 0.33 g, representing 1.1% of the body mass of the bat, less than the maximum of 5% recommended by Aldridge and Brigham (1988). This brand of skin cement is effective for adhesion of the tag to the bat for at least several days (Carter *et al.* 2009), and the transmitter battery life is expected to be as long as 21 days. Once the glue had dried, the bat was released at the capture site.

We attempted to relocate the bat by driving roads within 5 km of the capture site for seven days after capture, using two 4-element Yagi antennae fixed in opposite directions to the roof of a truck and connected to an SRX800 receiver (Lotek). The bat was

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never detected from the ground; thus, tracking its movements relied on detections on the Motus Wildlife Tracking System.

The Motus system is an international collaborative research network that uses coordinated automated radio telemetry arrays to study movements of small animals (Taylor *et al.* 2017); it has been used for tracking migratory bats (Lagerveld *et al.* 2017). Bird Studies Canada maintains an array of more than 100 automated radio telemetry stations in Ontario, and The Ohio State University maintains other stations in Ohio used by this study. Although these do not provide complete coverage of all areas and are not suitable for precise triangulation, detections show large landscape movements. Detection of tags at a receiver station could be within 15 km of the station depending on station strength and whether the animal is flying in the open or near obstructions (Taylor *et al.* 2017). The nearest receiver station to the capture site (Onondaga) was ~2 km south, but it was not activated until 12 July 2016 (seven days after we tagged the bat); the bat was never detected at this station.

Figure 1 depicts the movements of the bat, although it did not necessarily travel in a straight line between stations. The specific locations of the stations where it was detected are provided in Table 1 along with the dates and times when the bat was detected. Over two weeks, the Hoary Bat travelled a minimum distance of 827 km and was last detected only 46 km from the banding location. The landscape that it moved through was predominantly agricultural with scattered remnants of forest and wetland.

The male Hoary Bat made significant movements within short periods (Table 1): the longest were a minimum of 253 km over one night and 316 km over three nights (although it is unknown how long the

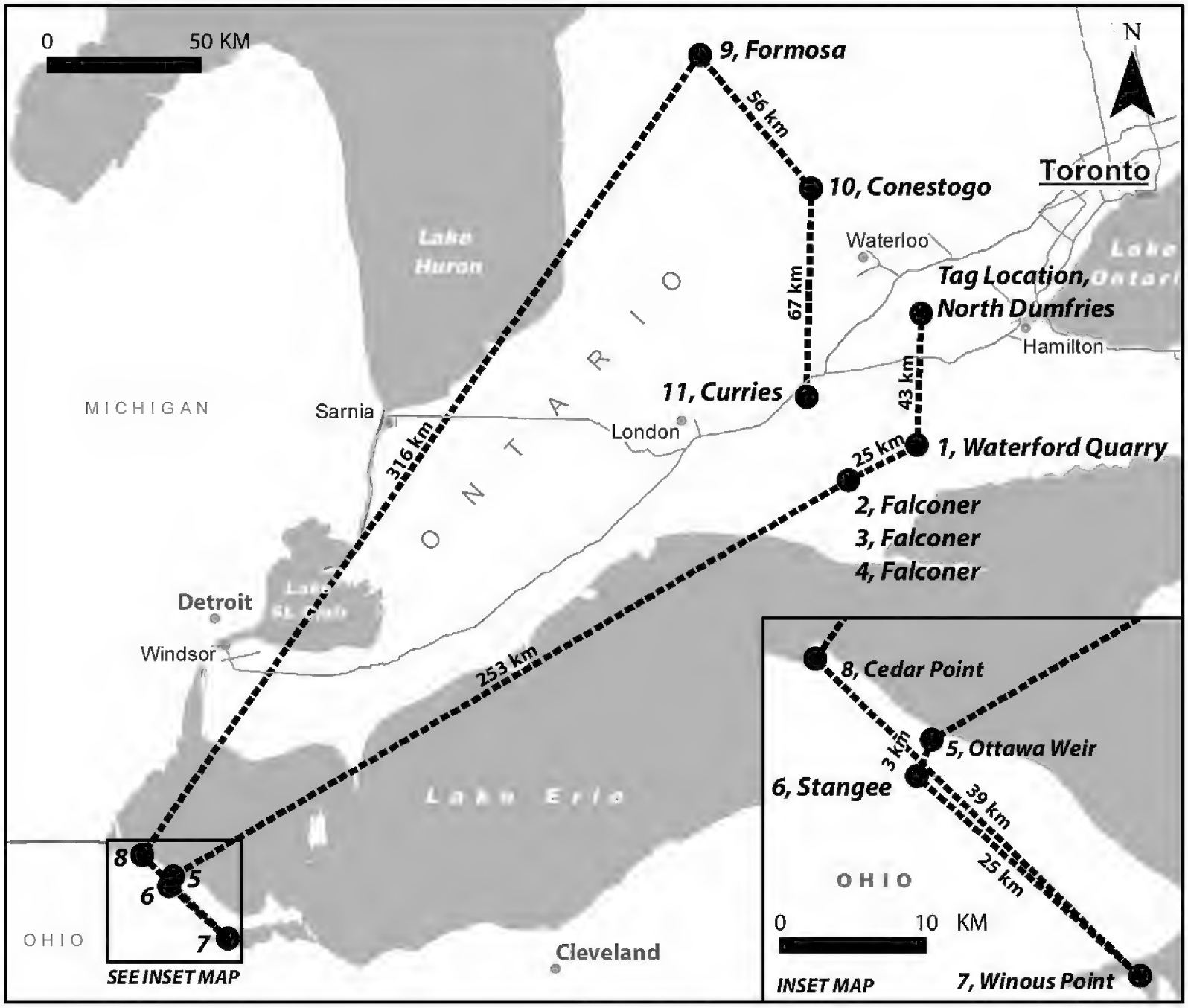

FIGURE 1. The map indicates the location where the male Hoary Bat (*Lasiurus cinereus*) was tagged on 9 July 2016 (North Dumfries) and its subsequent detections at the various Motus stations: 1. Waterford Quarry; 2, 3, 4. Falconer; 5. Ottawa Weir; 6. Stangee; 7. Winous Point; 8. Cedar Point; 9. Formosa; 10. Conestogo; 11. Curries. The inset map shows its movements in Ohio on 19 July 2016.

TABLE 1. Movements of a radio-tagged Hoary Bat (*Lasiurus cinereus*) over a 2-week period in July 2016 in southwestern Ontario.

Motus station*	Date and time detected	Distance from last station, km	Cumulative distance travelled, km
North Dumfries (tagging location)	9 July, 2350	0	0
1. Waterford Quarry	14 July, 1943–2200	43	43
2. Falconer	15 July, 2229–2303	25	68
3. Falconer	16 July, 2005	0	68
4. Falconer	18 July, 1912–1929	0	68
5. Ottawa Weir	19 July, 1728–1730	253	321
6. Stangee	19 July, 1732–1743	3	324
7. Winous Point	18 July, 1731–1736	25	349
8. Cedar Point	19 July, 1743–1744	39	388
9. Formosa	22 July, 1954–1955	316	704
10. Conestogo	22 July, 2129–2133	56	760
11. Curries	23 July, 2229–2349 24 July, 0156–0201	67	827

*Numbers correspond to those on the map in Figure 1.

bat took to fly these distances). The movements were not in a clear latitudinal direction. The bat initially moved to the southwest along or over Lake Erie, then flew quickly back to the northeast along or over Lake Huron and started another trip toward the southwest. It spent some time north of the Long Point area at Falconer and in the Cedar Point area of Ohio and was last detected at the Curries station (also near Long Point). The bat was detected consistently early in the night and often during daylight hours. If the bat was not moving at this time, we would have expected it to be detected repeatedly at individual stations until it moved out of the detection range. The bat did not appear to return to the location where it was captured during our sample period, because it was never detected at the Onondaga or other nearby stations.

Our study reports the first documented movements of an adult male Hoary Bat during the summer months. It has been widely believed that Hoary Bat makes long-distance movements during migration, but concrete evidence of this is sparse; even less information is available on local summer movements, such as those documented here. The few recoveries of banded Hoary Bats show maximum distances between banding and recovery sites of 150–450 km, representing more local movements (Davis 1969, 1970), although isotope analysis has shown that Hoary Bats make long-distance seasonal movements (Arias 2014; Baerwald *et al.* 2014).

In autumn in California, Weller *et al.* (2016) recovered three adult male Hoary Bats with global positioning system tags. One remained sedentary during the study, one made local movements of less than 100 km, and the third travelled over 1000 km in a month. Similar to the bat that we tracked, it moved in a circular manner and ended up less than 150 km from the original capture location. Results from this observation and Weller *et al.* (2016) indicate that male Hoary Bats may occasionally make circular or other long-distance movements lasting several days and covering distances as great as 1000 km. Although sample size is still very small (two of four tracked bats), this indicates that these bats have a large home range and, therefore, habitat protection or conservation for the species must similarly be on a large scale. The purpose of these flights is uncertain: bats may be searching for females to mate with before migration (Weller *et al.* 2016), although this bat was not scrotal (showing signs of sexual reproduction by having distended testes). More studies that use the Motus system or other methods capable of tracking Hoary Bats are recommended to better understand the space use by this fast, high-flying bat.

Hoary Bats are frequently killed at wind power facilities, particularly during late summer and autumn migration (Arnett *et al.* 2007; Bird Studies Canada *et al.* 2016). Hayes *et al.* (2015) concluded that Hoary Bats make up approximately 40–50% of all bat mortalities at wind farms; in Canada, this figure is 30.9% (Bird Studies Canada *et al.* 2016). Cryan (2011) estimated that as many as 225 000 Hoary Bats might be killed annually at North American wind farms, and it is predicted that the Hoary Bat population could decline by 90% in the next 50 years because of mortality related to wind turbines (Frick *et al.* 2017). Over the landscape that this bat travelled, a considerable number of wind turbines are in operation. Ontario has the greatest wind power generation in Canada with more than 4781 MWh of annual power production as of 2016 (Canadian Wind Energy Association 2017); many of the turbines are in southwestern Ontario. This bat either avoided those turbines or flew through them without being killed during the period that it was tracked. Our data provide

evidence that Hoary Bats are at risk of encountering a large number of wind turbines during their summer movements, not just during migration.

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A reconnaissance survey for Collared Pika (*Ochotona collaris*) in northern Yukon

Sydney G. Cannings[1], Thomas S. Jung[2,*], Jeffrey H. Skevington[3], Isabelle Duclos[4], and Saleem Dar[1]

[1]Canadian Wildlife Service, Environment and Climate Change Canada, Whitehorse, Yukon Y1A 5X7 Canada
[2]Yukon Department of Environment, Whitehorse, Yukon Y1A 2C6 Canada
[3]Agriculture and Agri-food Canada, Ottawa, Ontario K1A 0C6 Canada
[4]Canadian Wildlife Service, Environment and Climate Change Canada, Yellowknife, Northwest Territories X1A 2P7 Canada
*Corresponding author: thomas.jung@gov.yk.ca

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Abstract

Collared Pika (*Ochotona collaris*) is a cold-adapted Beringian species that occurs on talus slopes and is sensitive to climate warming. Collared Pikas are patchily distributed throughout the sub-Arctic mountains of northwestern Canada and Alaska; however, information on their occurrence in the northern part of their distributional range is limited. In particular, no survey information is known from the southern Richardson Mountains and the Nahoni Mountains. We conducted aerial- and ground-based surveys to document Collared Pika occurrence and general habitat suitability in northern Yukon. We flew 505 km of aerial survey (not including ferrying to targetted survey areas) and performed ground surveys at 22 sites within the Richardson Mountains (including a portion of Dàadzàii Vàn Territorial Park) and the Nahoni Mountains in and adjacent to Ni'iinlii Njik (Fishing Branch) Territorial Park. Overall, suitable habitat for Collared Pikas was patchy in the mountains of northern Yukon—talus was sparse and many patches of talus appeared to be unsuitable. Collared Pikas were detected at eight of 22 (36%) sites visited, representing important new records for the species in the northern portion of their range. Our reconnaissance provides a first approximation of habitat suitability for Collared Pikas of the mountains of northern Yukon, as well as new records for the species in the region. These data are useful in better determining the contemporary distribution of Collared Pika through species distribution modelling, and may serve to identify areas for more detailed survey and monitoring initiatives for this climate-sensitive mammal.

Key words: Collared Pika; Dàadzàii Vàn Territorial Park; distributional range; Ni'iinlii Njik (Fishing Branch) Territorial Park; *Ochotona collaris*

Introduction

Collared Pika (*Ochotona collaris*) is a small, cold-adapted mammal that is Beringian in origin (Lanier and Olson 2013; Lanier *et al.* 2015) and patchily distributed throughout the sub-Arctic mountains of Alaska and northwestern Canada (MacDonald and Jones 1987). Collared Pika are closely associated with talus (i.e., boulder fields) that is interspersed by alpine meadows (MacDonald and Jones 1987; Franken and Hik 2004; Morrison and Hik 2007). Talus provides Collared Pikas with critical protection from predators and inclement weather; as such, they are rarely found far from this habitat. However, not all talus is suitable for Collared Pika. In Tombstone Territorial Park (central Yukon, Canada), for instance, Collared Pika occupancy was positively associated with large patches of talus that had an average rock size of 30–100 cm, and where *Dryas* spp. and *Carex* spp. were available within and adjacent to the patch (L.M. Andresen *et al.* unpubl. data). Given that talus is naturally patchy on the landscape, Collared Pikas have a fragmented distribution. They have limited dispersal ability and are subject to metapopulation dynamics—whereby local populations may periodically become extinct—leaving apparently suitable habitat variably occupied (Franken and Hik 2004; Morrison and Hik 2007).

In Canada, Collard Pika has been assessed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), largely because of the threat of climate change (COSEWIC 2011). The region where the Collared Pika occurs is "experiencing climate-driven shifts in habitat, temperature, and precipitation at faster rates than elsewhere in Canada" (COSEWIC 2011). Climate-induced shrubification of alpine tundra (Danby and Hik 2007; Myers-Smith *et al.* 2011) is of chief concern re-

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garding the persistence of Collared Pika populations, as is the depth and duration of snowpack (Morrison and Hik 2007). Local populations of Collared Pikas in southwestern Yukon have declined due to variability in snowpack (Morrison and Hik 2007). This demonstrated sensitivity to climate-induced changes to their habitat, coupled with poor dispersal ability and the fragmented nature of their habitats, make Collared Pikas particularly vulnerable to climate change (Morrison and Hik 2007, 2008; COSEWIC 2011). As such, Collared Pika may be a useful bioindicator of climate change impacts to alpine ecosystems (Morrison and Hik 2008).

To assess the range-wide impact of climate change on Collared Pika, wildlife managers require better information on the current species distribution. Precise location data also may be used to develop accurate spatial distribution models that can then be used to predict changes in distribution under different climate change scenarios (e.g., Li *et al.* 2015; Struebig *et al.* 2015). Detailed monitoring and systematic surveys of Collared Pika have occurred in southwestern Yukon (Morrison and Hik 2008) and Tombstone Territorial Park (Kukka *et al.* 2014); however, information on their occurrence in the northern part of their distributional range is limited. In particular, no survey information was known from the southern Richardson Mountains and the Nahoni Mountains (i.e., Ni'iinlii Njik [Fishing Branch] Territorial Park).

The purpose of this study was two-fold: 1) to survey for the presence of Collared Pika in the northern portion of their range, and 2) to conduct a rapid assessment of the habitat suitability for this species in the Richardson Mountains (including Dàadzàii Vàn Territorial Park) and in the Nahoni Mountains (including in Ni'iinlii Njik [Fishing Branch] Territorial Park) in northern Yukon. To do so, we undertook a reconnaissance survey for Collared Pika and their habitat, using aerial- and ground-based surveys. Our aim was to provide new information on Collared Pikas in the northern portion of their distributional range so that these data can inform habitat modelling, monitoring, and management planning, initiatives for this species at risk.

Methods

We surveyed for Collared Pikas and their habitat in northern Yukon, Canada, during 3–6 July 2018. Specifically, we searched for suitable habitat in the Richardson Mountains east and north of Eagle Plains, Yukon (including a portion of Dàadzàii Vàn Territorial Park), as well as in the Nahoni Mountains (including Ni'iinlii Njik [Fishing Branch] Territorial Park), south of Old Crow, Yukon (Figure 1). We used an AStar helicopter (AS350B3; Eurocopter, Marignane, France) to provide an aerial overview of the habitat conditions in the survey area, and to locate the apparently most suitable habitat for ground-based surveys. We flew 100–400 m above ground level at slow speeds (i.e., 100–120 km/h) in suitable terrain (i.e., mountains) and searched for areas of extensive talus slopes and investigated these more closely. Based on occupancy models developed for Collared Pika in Tombstone Territorial Park (L.M. Andresen *et al.* unpubl. data) that identified predictive habitat covariates, we created four habitat suitability ranks to apply to observed talus slopes (Table 1). We applied these to broadly characterize the suitability of the talus as Collared Pika habitat.

At select sites (n = 22) we landed and searched talus areas for Collared Pika presence. We attempted to select the most suitable talus sites for ground surveys (i.e., habitat suitability rank 3 or 4; Table 1); however, where no such habitat was apparent we elected to search lower ranked areas of talus to ensure that we covered the possibility that Collared Pikas were selecting these sites based on their availability. At each site 4–5 observers searched separate talus patches for approximately 30–60 minutes to detect the presence of Collared Pikas. We walked along the perimeter of the talus patch, and also traversed portions of the talus to intersect potential Collared Pika territories. Pikas (*Ochotona* spp.) are highly territorial and vocalize when conspecifics or other species (including humans) enter their territory (Conner 1984; Trefry and Hik 2009). As such, we largely relied on acoustically detecting Collared Pika (Moyer-Horner *et al.* 2012). We also used binoculars to periodically scan for Collared Pika within the talus; however, Collared Pika are cryptically-coloured to match talus, and may be difficult to visually observe if they are not moving or vocalizing. Finally, pikas build easily recognizable hay piles and latrines within the talus (MacDonald and Jones 1987), and we also used these signs to detect their presence (Morrison and Hik 2008; Moyer-Horner *et al.* 2012; L.M. Andresen *et al.* unpubl. data). For each site surveyed we assigned a habitat suitability rank of 1–4 (poor to excellent; Table 1).

Results and Discussion

We flew 505 km of survey effort for Collared Pika in northern Yukon (not including ferrying to targetted survey areas). This effort included low-level aerial survey of 158 and 178 km of potential Collared Pika habitat (i.e., mountain slopes) in the southern and northern Richardson Mountains, respectively, and 169 km of potential habitat in Ni'iinlii Njik (Fishing Branch) Territorial Park (Figure 1).

While some mountains observed had large patches of talus (e.g., approximately ≥5 ha; Figure 2), in gen-

eral we did not observe extensive boulder fields in the same relative abundance as that found in Tombstone Territorial Park, likely because much of the Richardson and Nahoni mountains were unglaciated during the Last Glacial Maximum (Catto 1996). Quantity of talus, in general, was greatest during our survey in the northern Richardson Mountains, in and adjacent to Dàadzàii Vàn Territorial Park, with much of that observed being ranked as 3–4 (good–excellent) as Collared Pika habitat. In contrast, quantity of talus was low in the southern Richardson Mountains, and its suitability as Collared Pika habitat was ranked only as 1–2 (poor-marginal). Mountain peaks there were low and rounded and most talus observed was small (<30 cm) and unsuitable as Collared Pika habitat. Potential Collared Pika habitat was variable in the Nahoni Mountains, with some local areas having abundant talus of suitable characteristics (rank 2–4; marginal-excellent) and other areas have little talus available. Overall, we would rate the northern Richardson Mountains being most suitable as Collared Pika habitat in the areas we surveyed, although local areas in the Nahoni Mountains were also suitable. We observed little suitable Collared Pika habitat in the southern Richardson Mountains.

We detected Collared Pika presence at nine of 22

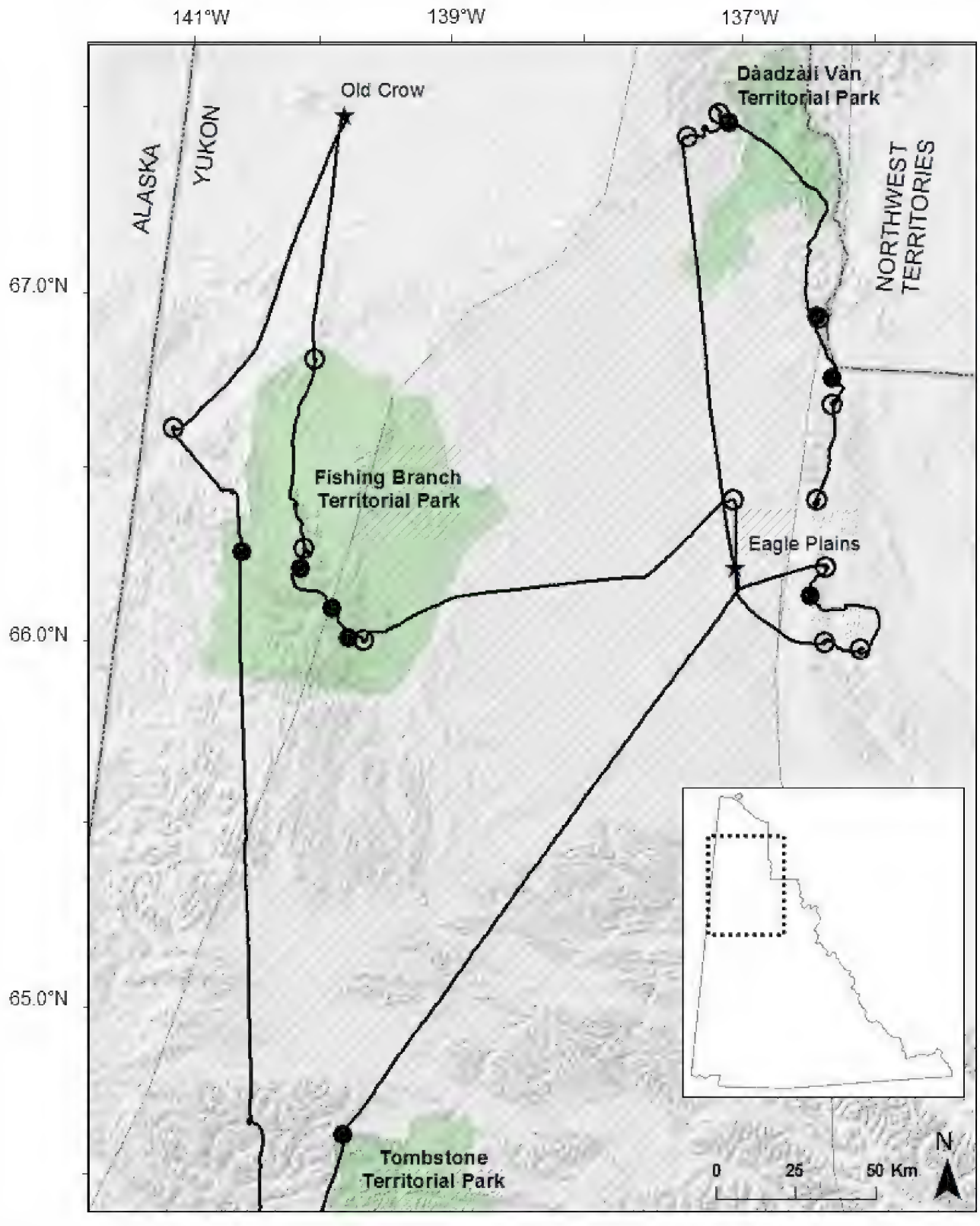

FIGURE 1. Flight path (black transect) of an aerial survey for Collared Pika (*Ochotona collaris*) and their habitat in northern Yukon. Closed circles are sites surveyed on the ground where Collared Pika was detected, and open circles where they were not detected. The stippled polygon represents the putative distributional range of Collared Pika (Lanier and Hik 2016). Stars indicate human settlements. Site numbers are in Table 2. The insert shows the study area situated within Yukon, Canada.

TABLE 1. Description of habitat suitability ranks given to areas surveyed for Collared Pika (*Ochotona collaris*) in northern Yukon, July 2018.

Habitat suitability rank	General description
1	Poor habitat quality: Average rock size <30 cm or >100 cm with many smaller rocks that fill in the interstitial spaces between the larger rocks.
2	Marginal habitat quality: Average rock size 30–100 cm, but with areas of extensive shrub cover in and around the talus, or with no to small amounts of *Dryas* spp. cover adjacent to talus, or many smaller rocks that fill in the interstitial spaces between the larger rocks.
3	Good habitat quality: Average rock size 30–50 cm; large area covered by talus slopes that are interspersed with non-shrubby patches of vegetation including *Dryas* spp.
4	Excellent habitat quality: Average rock size 50–100 cm; large area covered by talus slopes that are interspersed with non-shrubby patches of vegetation including extensive *Dryas* spp. cover.

FIGURE 2. Photograph of site 8 (see Table 2)—an example of the site characteristics where Collared Pika (*Ochotona collaris*) were observed in northern Yukon, Canada. Photo: J.H. Skevington.

sites surveyed on the ground (Table 2; Figure 1). One of these sites was just outside the northern boundary of Tombstone Territorial Park, where Collared Pika are already known and monitored (Kukka *et al.* 2014; Figure 1). We detected Collared Pika at three of five and one of seven sites surveyed in the northern and southern Richardson Mountains, respectively, and four of eight sites in the Nahoni Mountains (Figure 1). At two sites (sites 4 [Figure 3a] and 11; Table 2) we detected only old sign of Collared Pika, indicating that the population may have been extirpated. This included the single site where we detected Collared Pika in the southern Richardson Mountains (site 4, Table 2). Although our survey was not designed to estimate the density of Collared Pika at our sites, it appeared that they persisted at low densities at all the sites where they were detected. In only one instance did we detect more than a single individual at a site. In suitable habitat in southwestern Yukon, Collared Pika density is estimated at <1 to 4 individuals per ha (Morrison and Hik 2007).

Habitat suitability was variable among the 22 sites we surveyed on the ground, with 36% of them having poor-marginal (1–2 ranks) and 64% having good-excellent (3–4 ranks) habitat suitability ranks (Table 2). Collared Pikas were detected at only one of eight sites that were of poor-marginal habitat suitability, but they were detected at seven of 14 sites we classified as being of good-excellent habitat suitability (Figures 2 and 3). Anecdotally, the most limiting habitat features at the sites we surveyed were likely the average rock size being <50 cm, coupled with many sites having extensive shrubby vegetation in and around the talus (as opposed to *Dryas* spp. and other forage plants; L.M. Andresen *et al.* unpubl. data). The elevation where we detected Collared Pika was variable with a mean of 961.1 ± 175.8 m (SD; range = 685–1329 m; Table 2).

Other mammals or their sign (e.g., burrows, diggings, dens, scat, antlers) detected at our survey sites for Collared Pika included Grizzly Bear (*Ursus arctos*), Wolverine (*Gulo gulo*), Dall's Sheep (*Ovis dalli*), Caribou (*Rangifer tarandus*), Muskox (*Ovibos moschatus*), Moose (*Alces americanus*), Arctic Ground Squirrel (*Urocitellus parryii*), and small rodents (likely Singing Vole [*Microtus miurus*], Tundra Vole [*Microtus oeconomus*], Northern Red-backed Vole [*Myodes rutilus*], or Brown Lemming [*Lemmus trimucronatus*]; Table 2). Notably, we did not observe any sign of Hoary Marmot (*Marmota caligata*) during our survey. Moreover, Arctic Ground Squirrels were surprisingly not abundant at any of the sites we surveyed north of the Ogilvie Mountains, where there they are often on mountains associated with Collared Pika (T.S.J. pers. obs.). We detected Arctic Ground Squirrels at only six of 21 (29%) sites that were surveyed north of the Ogilvie Mountains.

Our reconnaissance of the mountains of northern Yukon provides a first approximation of habitat suitability for Collared Pikas, as well as important new records for the species, in the northern portion of their distributional range. These data are useful in determining the contemporary distribution of Collared Pika through species distribution modelling and may serve to identify areas for more detailed survey and monitoring initiatives for this

TABLE 2. Description of sites surveyed for Collared Pika (*Ochotona collaris*) in northern Yukon, 3–6 July 2018.

Site	Habitat rank*	Collared Pika detected	Detection type†	Location	Elevation (m)	Other mammals observed‡
1	3	Yes	1, 2	64.77657°N, 139.08717°W	1329	1, 2, 3, 6, 7
2	1	No	—	66.24000°N, 136.09439°W	1092	1, 2, 7
3	3	No	—	66.22826°N, 135.84087°W	771	1, 5, 7
4	2	Yes	3	66.36445°N, 136.21266°W	944	3, 5, 7
5	1	No	—	66.44556°N, 136.11227°W	851	1, 2, 7
6	1	No	—	66.62994°N, 136.20248°W	1205	1, 2, 7
7	2	No	—	66.89725°N, 136.13144°W	565	1, 3, 5, 7
8	3	Yes	2	66.96921°N, 136.14555°W	927	1, 2, 3, 7
9	4	No	—	67.13135°N, 136.26424°W	1011	1, 2, 3, 4, 7
10	3	Yes	2	67.13584°N, 136.27515°W	862	5, 6
11	4	Yes	3	67.65533°N, 137.01370°W	1047	1, 2, 3, 5, 6, 7
12	3	No	—	67.67641°N, 137.08986°W	941	2, 3, 7
13	4	No	—	67.60668°N, 137.31078°W	957	1, 2, 3, 7
14	2	No	—	66.61674°N, 136.79306°W	873	3
15	3	No	—	66.13930°N, 139.29184°W	994	1, 6, 7
16	3	Yes	2	66.14023°N, 139.39793°W	817	1, 5, 6, 7, 8
17	3	Yes	2	66.21690°N, 139.53180°W	685	5, 6, 7
18	4	Yes	1, 2, 3	66.31663°N, 139.78535°W	1120	1, 2, 3, 6, 7
19	1	No	—	66.37148°N, 139.77873°W	871	1, 5
20	2	No	—	66.89491°N, 139.85330°W	984	1, 2, 5, 6, 7
21	1	No	—	66.65713°N, 140.79265°W	680	5, 7
22	3	Yes	2	66.34312°N, 140.20544°W	919	5, 7

*See Table 1 for habitat suitability rank descriptions.
†Detection types as follows: 1 = visual, 2 = acoustic, 3 = sign (haypiles or latrines).
‡Codes for other mammals as follows: 1 = Grizzly Bear (*Ursus arctos*), 2 = Dall's Sheep (*Ovis dalli*), 3 = Caribou (*Rangifer tarandus*), 4 = Muskox (*Ovibos moschatus*), 5 = Moose (*Alces americanus*), 6 = Arctic Ground Squirrel (*Spermophilius parryii*), 7 = voles or lemmings, 8 = Wolverine (*Gulo gulo*).

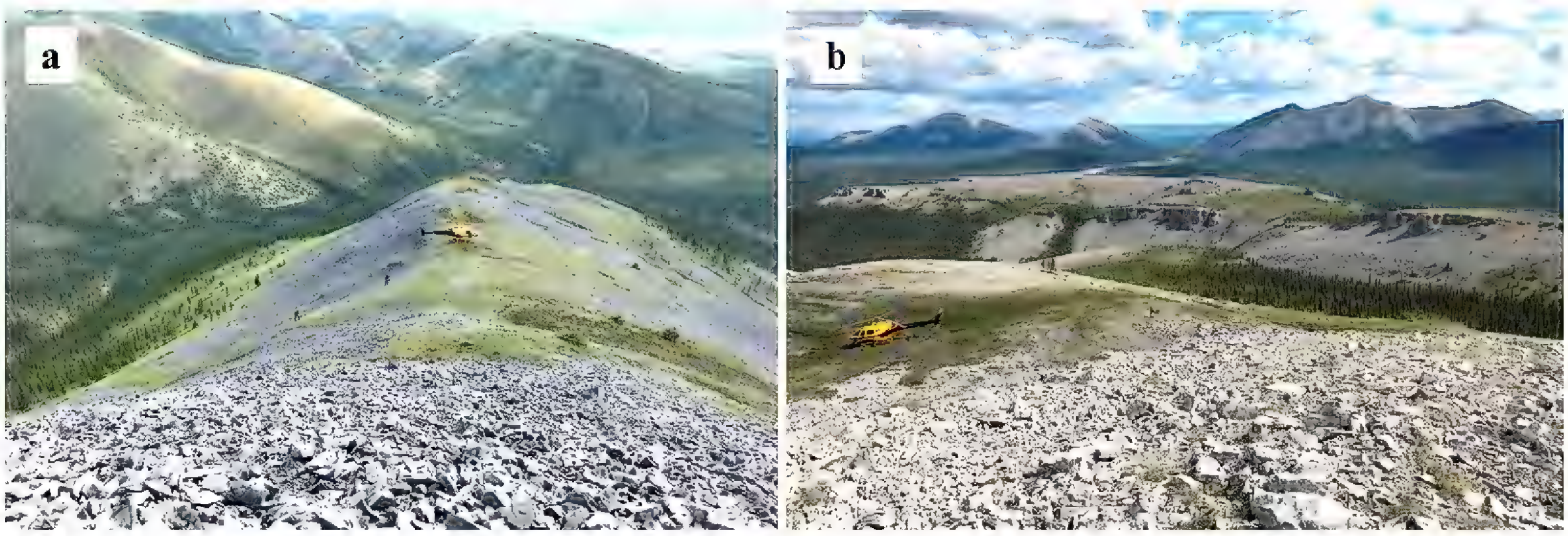

FIGURE 3. Photographs of the general habitat conditions at select survey sites for Collared Pika (*Ochotona collaris*) in the southern Richardson Mountains (a is site 4) and Nahoni Mountains (b is site 15) in northern Yukon, Canada. Photos: J.H. Skevington.

climate-sensitive mammal. We suggest that Collared Pika presence and habitat suitability was good in the northern Richardson Mountains, moderate-to-good in the Nahoni Mountains, and poor in the southern Richardson Mountains. We emphasize, however, that our work is preliminary in nature and our ability to thoroughly survey our target areas was limited; thus, this region would benefit from further survey effort. Preliminary habitat suitability mapping in northern Yukon, using imagery from remote sensing to map large patches of talus, would likely be helpful in determining other sites with a high probability of Collared Pika occurrence. We suggest that the northern Richardson Mountains (in and adjacent to Dàadzàii Vàn Territorial Park) would be an important area to focus future survey efforts, perhaps in conjunction with similar surveys for other small mammals of conservation interest in the region (e.g., collared lemmings [*Discrostonyx* spp.]; Jung *et al.* 2014).

Acknowledgements

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Note

Occurrence of the rare marine littoral millipede, *Thalassisobates littoralis* (Diplopoda: Nematosomatidae), in Canada

Donald F. McAlpine

New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada; email: donald.mcalpine@nbm-mnb.ca

McAlpine, D.F. 2019. Occurrence of the rare marine littoral millipede, *Thalassisobates littoralis* (Diplopoda: Nematosomatidae), in Canada. Canadian Field-Naturalist 133(2): 136–138. https://doi.org/10.22621/cfn.v133i2.2215.

Abstract

The first Canadian occurrence of the rare, marine littoral millipede, *Thalassisobates littoralis*, is reported from Campobello Island in the outer Bay of Fundy, New Brunswick. One of only a few North American occurrences, this is the most northerly to date from the continent.

Key words: New Brunswick; marine habitat; marine millipede; dispersal; anthropochorus species; *Thalassisobates littoralis*

World-wide, *Thalassisobates littoralis* (Silvestri, 1903) (no common name) is one of the few marine littoral millipedes and is considered rare (Blower 1985; Barber 2009). The species occurs under stones and seaweed, in rock crevices or shingle in or above the tidal zone, and sometimes in coastal caves (Enghoff 1987; Cawley 1997). *Thalassisobates littoralis* has a wide but scattered distribution, with reports (often single) from the coasts of Europe, the Balearic Islands, Algeria, and the eastern United States (Enghoff 2013). The centre of its distribution appears to be the western Mediterranean basin (Kime 1999), with Kime (1999) suggesting that *T. littoralis* may have been introduced to northwestern Europe. Reporting the first North American occurrences, Enghoff (1987) speculated that the species was of European origin, but was uncertain whether its amphi-Atlantic distribution was natural or the result of human introduction. He noted that all amphi-Atlantic millipedes previously reported from North America, with one possible exception, can be regarded as introductions to the continent and that the direction of the Gulf Stream is not conducive to the natural dispersal of *T. littoralis* from Europe to North America. Thus, not unreasonably, *T. littoralis* has been considered of anthropochorus origin in North America (Kime 1999; Golovatch and Kime 2009).

Previously, *T. littoralis* has been recorded in North America only from the southwest shore of Chincoteague Island, Virginia, in 1964, from an unknown locale in Massachusetts (date unknown; Enghoff 1987), and, more recently (2005–2009), from six of the 34 islands that make up the Boston Harbor Recreation Area (Boston Harbor Islands 2014). Here, I document the first occurrence of *T. littoralis* from Canada and the most northerly to date on the North American continent.

On 24 September 2017, I found *T. littoralis* to be present, but patchily distributed, along a cobble shoreline at Herring Cove, in Herring Cove Provincial Park, Campobello Island, New Brunswick (44.85956°N, 66.93188°W), along the western shore of the Bay of Fundy. Millipedes were present under patches of decomposing Bladderwrack (*Fuscus vesiculosus*) above and below the high-water mark (Figure 1a). Where present, millipedes were abundant (Figure 1b). In a sample of 104 specimens, 55 females and 49 males were present, close to a 1:1 sex ratio. The whole body of a single male (Figure 1c) and a series of views of the male peltogonopods, diagnostic for *T. littoralis*, are shown in Figure 1d–f. Voucher specimens have been deposited in the New Brunswick Museum (NBM 10776).

After the discovery of *T. littoralis* on Campobello Island, two other cobble beach sites in New Brunswick were searched along the western coast of the Bay of Fundy (Alma, 45.596739°N, 64.948728°W, and Browns Beach, West Quaco, 45.319236°N, 65.551114°W), for *T. littoralis* without success. Further field investigations will be required to determine

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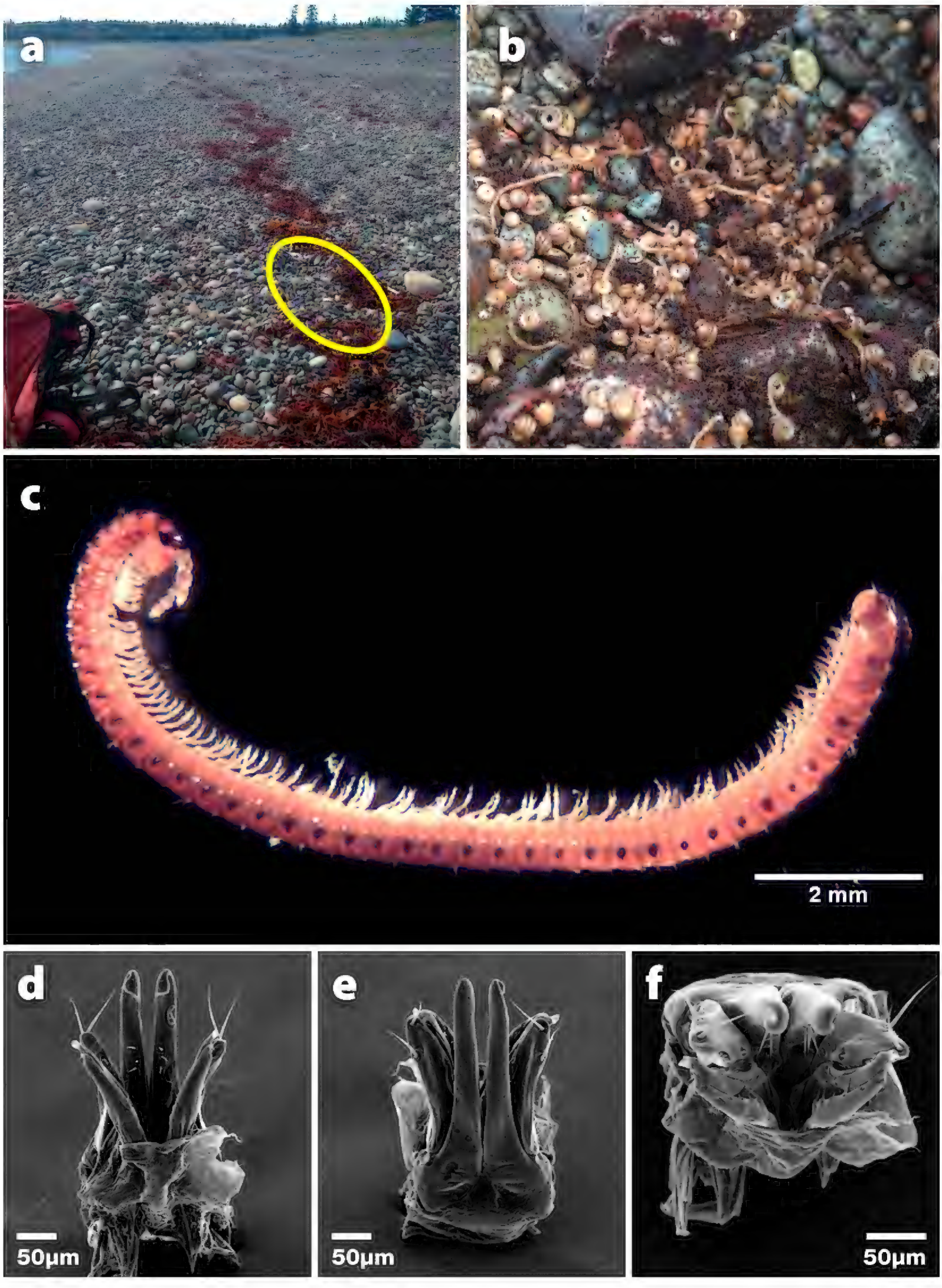

Figure 1. a. Shoreline at Herring Cove Provincial Park, New Brunswick, showing habitat for *Thalassisobates littoralis*. b. Concentration of millipedes under Bladderwrack (*Fuscus vesiculosus*). c. Habitus of male *T. littoralis*; scanning electron microscope images show d. superior, e. inferior, and f. distal views of the diagnostic peltogonopods. Photos: a–b. D.F. McAlpine. Photos: c–f. Nhu Trieu.

the full distribution and true abundance of *T. littoralis* in Atlantic Canada.

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A practical technique for preserving specimens of duckmeal, *Wolffia* (Araceae)

Daniel F. Brunton

216 Lincoln Heights Roads, Ottawa, Ontario KIA 8A8; email: bruntonconsulting@rogers.com

Brunton, D.F. 2019. A practical technique for preserving specimens of duckmeal, *Wolffia* (Araceae). Canadian Field-Naturalist 133(2): 139–143. https://doi.org/10.22621/cfn.v133i2.2108

Abstract

Making identifiable herbarium vouchers of the minute aquatic vascular plant duckmeal, *Wolffia* (Lemnoideae; Araceae) has typically required plants to be preserved in transparent, space-consuming vials that are fragile, difficult to work with, and labourious to prepare. An alternative technique for dry-mounting *Wolffia* within a layer of transparent, acid-free glue presents a promising alternative. Although the largely water-filled individual plants still compress substantially, this preparation technique results in specimens that retain their colour, size, and, most important, their shape. This greatly enhances the possibility of confident identification and simplifies both specimen preparation and storage.

Key words: *Wolffia*; Lemnoideae; Araceae; herbarium specimen preparation; storage

Introduction

Dore (1957) described the difficulty collectors face in securing voucher specimens of duckmeal (*Wolffia* spp., Lemnoideae, Araceae; also known as watermeal) in a condition that permits their re-examination and identification. Three species of this minute, simple plant, which is uncommon to rare throughout most of its Canadian range, typically form dense, floating mats (Figure 1) consisting of thousands and even millions of individuals (Brunton 2018; Brunton and Bickerton 2018). At least two *Wolffia* species (Figure 2) are native in southern Ontario and Quebec (Crow and Hellquist 2000). Individuals of this, the smallest flowering plant in the world, shrivel up into greenish-brown dust when air dried as conventional vascular plant herbarium specimens (Figure 3). This deformation eliminates the possibility of further identification, which is heavily dependent on plant shape characteristics (Crow and Hellquist 2000). Accordingly, the potential use of such material for taxonomic or phytogeographic analysis is substantially reduced.

Dore's (1957) solution to that curatorial challenge was to place *Wolffia* samples in a preservative fluid (alcohol) in a sealed glass vial, which was then attached to a standard herbarium sheet. Although this technique permits the voucher plants to retain their shape and size, it is an involved process that results in a slurry of colourless plants floating in a cumbersome, fragile vessel that takes up considerable space in a conventional herbarium arrangement. Individual plants also move freely within the vial and are difficult to follow or relocate. Unless the vial is opened (necessitating repetition of the entire voucher preparation process), the view of individual plants is also obscured and distorted by the glass container. There is a risk of breakage or leakage of the vials, as is evident in Dore's collection preserved in the Agriculture and Agri-Food Canada herbarium (DAO). In addition, the alcohol-filled vials are sealed with a flame or heat, a process that requires some experience and poses potential hazards (P.M. Catling pers. comm. 14 March 2019). Although preferable to simply drying plants into an unrecognizable condition, the vial solution is a cumbersome and unsatisfying curatorial response.

The easy availability of high-quality digital imagery in the field now provides a practical enhancement of the traditional air-dried voucher technique, because hard-copy images of fresh (pre-dried) voucher material can be affixed to the voucher sheet. However, photographs are only two-dimensional representations and cannot be used for detailed morphological studies.

Discussions with numerous field botanists in eastern Canada have confirmed that the difficulty in securing reasonable quality *Wolffia* vouchers significantly discourages their collection. This represents a floristic and conservation problem in Ontario and Quebec where Northern Duckmeal (*Wolffia borealis* (Engelmann) Landolt & Wildi ex Gandhi, Wiersema & Brouillet) (= *Wolffia punctata* Grisebach) and Co-

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FIGURE 1. Dense duckmeal (*Wolffia* spp.) mat completely covering creek surface. 8 August 2011, Beachburg, Renfrew County, Ontario. Photo: D.F. Brunton.

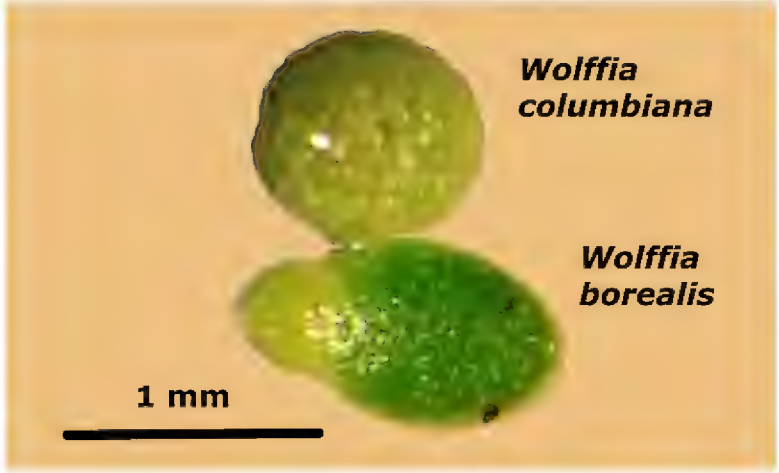

FIGURE 2. Fresh (live) Ontario native duckmeal (*Wolffia*) species. 31 July 2011, Peterborough County, Ontario, D.F. Brunton & K.L. McIntosh 17,896B. Photo: D.F. Brunton.

FIGURE 3. Shrivelled air-dried Northern Duckmeal (*Wolffia borealis*). 31 July 2011, Peterborough County, Ontario, D.F. Brunton & K.L. McIntosh 17,896B. Photo: D.F. Brunton.

lumbia Duckmeal (*Wolffia columbiana* H. Kirsten) (= *Wolffia arrhiza* auct., non (L.) Horkel) are almost always regionally uncommon (Dore 1957; Soper 1962; Oldham 2017) and the possibly introduced Papillate Watermeal (*Wolffia brasiliensis* Weddell) is rare (Thomson 2005). Both *W. borealis* and *W. columbiana* are considered rare and of conservation concern in Quebec (Tardif *et al.* 2005). In addition, populations are increasingly being found beyond *Wolffia*'s traditional northern limit along the southern edge of the Canadian Shield in Ontario (Soper 1962), suggesting ongoing range expansion (Brunton 2018).

Does this change represent climate change? Increased populations of certain waterfowl species? Transportation by human activity? All of the above? That is not clear, but the range of *Wolffia* unquestionably is enlarging in Canada and new *Wolffia* occurrences must be recorded with voucher specimens to document this and assess its implications. Accordingly, a practical procedure for producing informative vouchers is an important part of addressing these questions.

The dry-mounted specimen preparation technique described in this paper is an adaptation of the method described by Brunton (1990) for securing mass samples of even smaller and more fragile megaspores of the aquatic lycophyte *Isoetes* (quillwort) in a readily examinable state. This new dry-mounting procedure has been used to prepare samples in approximately two dozen *Wolffia* collections to date. It has resulted in vouchers of superior quality and utility in comparison to most vouchers prepared using traditional methods.

Methods

A small (5–10 mL) sample of fresh *Wolffia* plants is placed in a plastic or glass vial with enough of the water-diluted (ca. 75% of full strength), acid-free glue commonly used in herbarium specimen preparation to maintain the sample free floating. The glue used here was commercially available Weldbond Universal Adhesive (Frank T. Ross & Sons Ltd., Markham Ontario, Canada). No attempt was made to assess the performance of other commercial brands of adhesive, but it is suspected that any water-soluble white herbarium glue would perform comparably. The sample is left to soak for ~48 h. The container is covered to prevent the glue from drying and solidifying. Because *Wolffia* plants are exceedingly buoyant, the slurry of plants is stirred periodically (two or three times in the course of the soaking period) to ensure thorough contact with the glue solution.

After about 25–30 h, the colour of the glue solution takes on a distinctively green cast. The *Wolffia* plants also appear to be less buoyant, floating lower in the solution and remaining submerged slightly longer when stirred. This is interpreted as indicating that the plants have become slightly waterlogged and that the glue has penetrated their tissues.

After ~48 h the slurry is spread (poured) onto a sheet of plain paper (a heavier gauge, pH neutral paper is recommended) or directly onto a herbarium sheet (White 100 Percent Rag Bond – neutral pH 20 or 24 lb; Herbarium Supply Co., Bozeman, Montana, USA) in as thin a layer as possible and allowed to air dry. Concentrations of plants on the mounting sheet can be thinned by gently passing a dissection needle or probe through them. This must be done immediately after the slurry has been poured, however, as the solution becomes too tacky for smooth manipulation within as little as 10 min. The sample (Figure 4) is dry and ready for examination or processing as a herbarium specimen within about 2 h.

Results

Applying this voucher preparation technique to over 30 samples of native Ontario *Wolffia* involving 23 separate collections (Appendix 1) has produced encouraging results. Although the dry, glue-impregnated plants are completely deflated and flattened, they have, for the most part, retained their original size, shape, and colour (Figure 5). Some aspects of their morphology remain evident: for example, the punctate (dotted) surface of *W. borealis* is clearly visible in the dried plants.

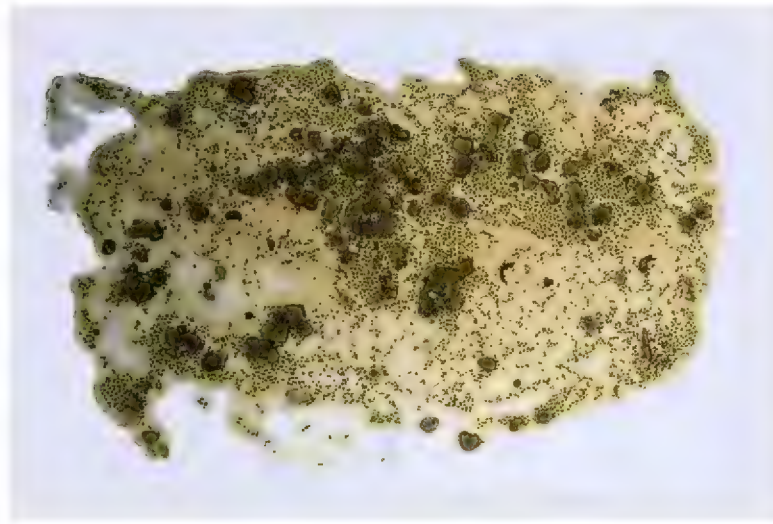

FIGURE 4. Sample of dried, glue-impregnated Columbia Duckmeal (*Wolffia columbiana*); larger intermixed plants are *Spirodella polyrhiza* (L.) Schleiden. 25 August 2017, Renfrew, Renfrew County, Ontario, D.F. Brunton & K. Fleming 19,783. Photo: D.F. Brunton.

Rehydrating shrivelled, long-dried herbarium material may also be worthwhile. In the two samples tested, the glue solution did not become as green as it did with fresh material, suggesting that the rehydrating plants do not become as completely saturated. Nonetheless, the rehydrated material was more distinguishable than it would have been if specimens had only been air dried.

It is recommended that collectors making *Wolffia* vouchers include a packet of air-dried plants ("green dust") prepared in the traditional way as well. This typically indistinguishable air-dried material is potentially useful for chemical and molecular analyses. Ideally, photos of fresh plants should be included in the voucher. When used in combination with glue-impregnated plants, these additional specimen components provide the most complete vouchers possible for multidisciplinary investigations.

More extensive experimentation would refine the technique described here. It may well provide similarly satisfying results, for example, for other aquatic plants that occur in vast numbers of minute individuals, such as duckweed (*Lemna*), duck-meat (*Spirodela*), and mud-midget (*Wolffiella*). A variation on this technique to accommodate larger specimens might also prove useful for the preservation of exceptionally delicate and/or fragile water nymph (*Najas*), ditchgrass (*Ruppia*), horned pondweed (*Zannichellia*), and

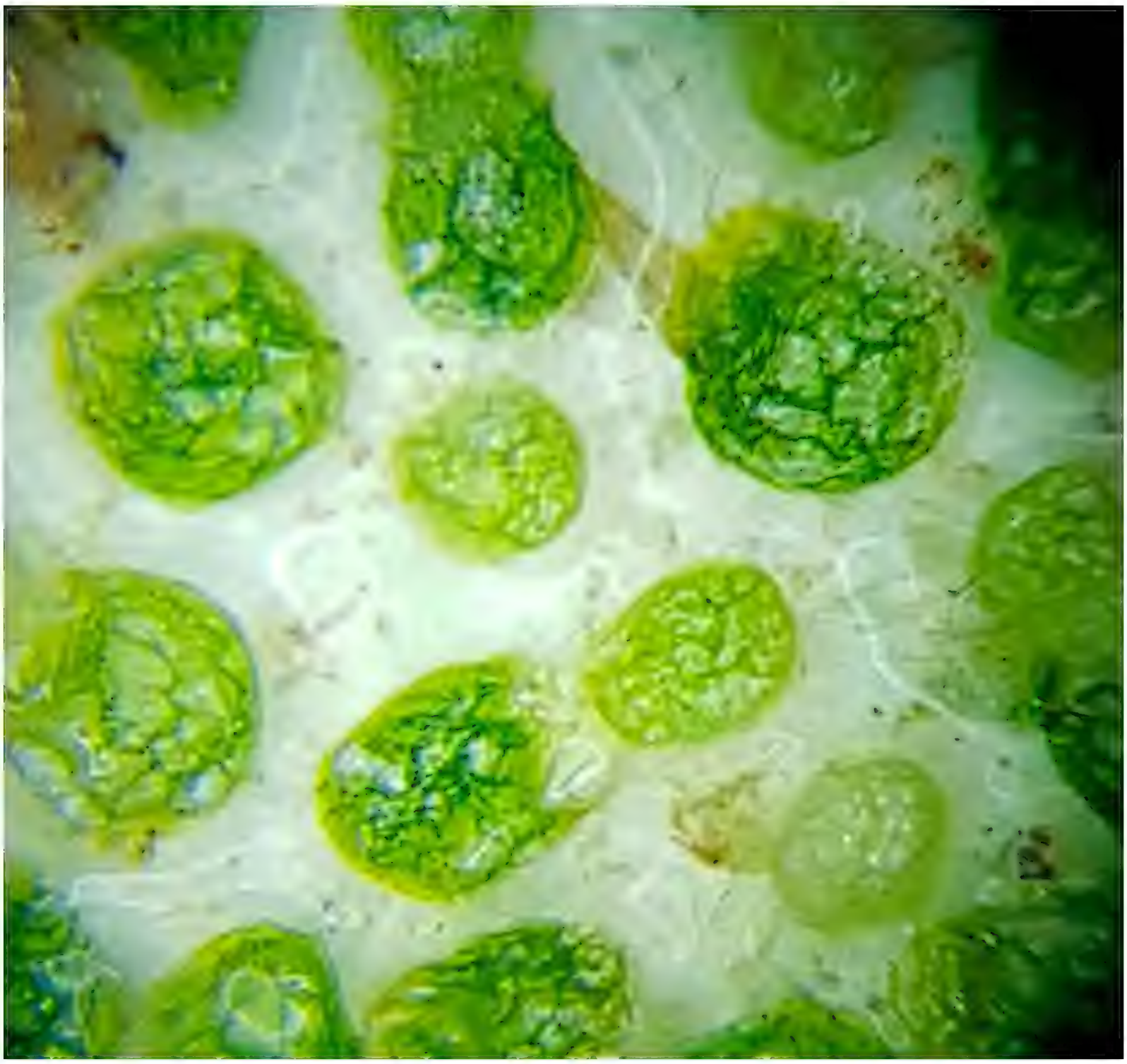

FIGURE 5. Close-up of glue-impregnated Columbia Duckmeal (*Wolffia columbiana*) retaining shape and size. 25 August 2017, Renfrew, Renfrew County, Ontario, D.F. Brunton & K. Fleming 19,783. Photo: D.F. Brunton.

pondweed (*Potamogeton* and *Stuckenia*) plants in a more natural form. As currently understood, however, this technique provides a logistically simple, space-efficient, permanent preservation alternative for making *Wolffia* vouchers, for which there is an immediate need. The technique has the added benefit of being hazard free for the preparator and posing no curatorial risks to associated herbarium material.

Acknowledgements

This paper benefited significantly from input by Associate Editor, Paul M. Catling, and reviewers, Bruce Ford, University of Manitoba, Winnipeg, Manitoba, Garret Crow, Calvin College, Grand Rapids, Michigan, and Michael J. Oldham, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. Their valuable comments and observations were based on extensive first-hand field experience with *Wolffia*. The author was inspired to investigate and collect these curious and challenging aquatic plants in the first place by the enthusiastic encouragement and assistance of the late W.G. (Bill) Dore (1912–1996), then of Agriculture Canada, Ottawa.

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Appendix 1: *Wolffia* specimens prepared, partly or entirely, using the Weldbond technique. Herbarium acronyms of Thiers (continuously updated).

Wolffia borealis

Ontario: City of Ottawa, 45.36843°N, 75.79522°W, west end of Turtle Bay, southwest portion of Mud Lake, Britannia Conservation Area, D.F. Brunton 17,106, 7 September 2007 (DFB);

Ontario: City of Ottawa, 45.33572°N, 75.92777°W, in Shirley's Brook along south side of Trillium Woods, South March Highlands, Kanata, D.F. Brunton 17,125, 5 October 2007 (DFB);

Ontario: City of Ottawa, 45.39846°N, 75.96812°W, south end of Constance Lake by inlet of Constance Creek, West Carleton, D.F. Brunton 18,036, 13 August 2011 (CAN, DFB);

Ontario: City of Ottawa, 45.34581°N, 75.86959°W, abandoned sewage treatment plant 395 m south southeast of Range Road/Carling Avenue intersection, Nepean, D.F. Brunton 18,913A, 8 October 2014 (WIN, DFB);

Ontario: Frontenac County, 44.27868°N, 76.59344°W, west side of Collins Creek north side of Creeksford Road, Kingston, D.F. Brunton 18,050A, 24 August 2011 (WIN, DFB);

Ontario: Peterborough County, 44.76643°N, 78.49064°W, west side of White's Lake Road, north side of Crystal Lake, Galway & Cavendish Township, D.F. Brunton and K.L. McIntosh 17,986B, 12 July 2011 (DFB);

Ontario: Peterborough County, 44.38742°N, 77.97751°W, east side of mill pond by outlet, north side of Highway 7, east end of Norwood, Asphodel Township, D.F. Brunton 19,916, 6 September 2017 (DFB).

Wolffia columbiana

Ontario: City of Ottawa, 45.36843°N, 75.79522°W, west end of Turtle Bay, southwest portion of Mud Lake, Britannia Conservation Area, D.F. Brunton 17,107, 7 September 2007 (DFB);

Ontario: City of Ottawa, 45.33572°N, 75.92777°W, in Shirley's Brook along south side of Trillium Woods, South March Highlands, Kanata, D.F. Brunton 17,126, 5 October 2007 (DFB);

Ontario: City of Ottawa, 45.39846°N, 75.96812°W, south end of Constance Lake by inlet of Constance Creek, West Carleton, D.F. Brunton 18,035, 13 August 2011 (CAN, DFB);

Ontario: City of Ottawa, 45.34581°N, 75.86959°W, abandoned sewage treatment plant 395 m south-southeast of Range Road/Carling Avenue intersection, Nepean, D.F. Brunton 18,913B, 8 October 2014 (WIN, DFB);

Ontario: Frontenac County, 44.27868°N, 76.59344°W, west side of Collins Creek north side of Creeksford Road, Kingston, D.F. Brunton 18,050B, 24 August 2011 (WIN, DFB);

Ontario: Peterborough County, 44.38742°N, 77.97751°W, east side of mill pond by outlet, north side of Highway 7, east end of Norwood, Asphodel Township, D.F. Brunton 19,917, 6 September 2017 (DFB);

Ontario: Peterborough County, 44.76643°N, 78.49064°W, west side of White's Lake Road, north side of Crystal Lake, Galway & Cavendish Township, D.F. Brunton and K.L. McIntosh 17,986B, 312 July 2011 (WIN, UBC, DFB);

Ontario: Renfrew County, 45.5128°N, 76.7591°W, 650 m north of Highway 60 at southeast corner of Clubhouse Lake, west side of Renfrew Golf Club, Horton Geographic Township, D.F. Brunton and K. Fleming 19,873, 27 August 2017 (DFB).

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The Canadian Field-Naturalist

Note

Sighting rates and prey of Minke Whales (*Balaenoptera acutorostrata*) and other cetaceans off Cormorant Island, British Columbia

Jared R. Towers[1,2,*], Christie J. McMillan[1], and Rebecca S. Piercey[3]

[1]Marine Education and Research Society, P.O. Box 1347, Port McNeill, British Columbia V0N 2R0 Canada
[2]Bay Cetology, P.O. Box 554, Alert Bay, British Columbia V0N 1A0 Canada
[3]Hakai Institute, P.O. Box 309, Heriot Bay, British Columbia V0P 1H0 Canada
*Corresponding author: jrtowers@gmail.com

Towers, J.R., C.J. McMillan, and R.S. Piercey. 2019. Sighting rates and prey of Minke Whales (*Balaenoptera acutorostrata*) and other cetaceans off Cormorant Island, British Columbia. Canadian Field-Naturalist 133(2): 144–150. https://doi.org/10.22621/cfn.v133i2.2103

Abstract

From June to August 2012, we conducted over 500 h of visual surveys from Cormorant Island, British Columbia, to determine behaviour and habitat use patterns of nearby cetaceans. Seven species were documented, but Minke Whales (*Balaenoptera acutorostrata*) were by far the most common and were observed lunge feeding at the surface on 15 occasions. In addition, this species was documented surface lunge feeding on Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*) on 32 occasions during vessel-based cetacean surveys around Cormorant Island between 2010 and 2014. Although Minke Whales are relatively uncommon in British Columbia, these results indicate that they can regularly be found in specific feeding areas during the summer.

Key words: Minke Whale; *Balaenoptera acutorostrata*; habitat use; feeding ground; Pacific Herring; *Clupea pallasi*; Pacific Sand Lance; *Ammodytes personatus*; Cormorant Island; British Columbia

The coastal waters of the eastern North Pacific are home to several species of cetaceans. Many have been exploited by humans and conservation concerns have made them the focus of extensive field studies in recent decades (Ford 2014). Important foraging habitats considered critical for recovery have been identified for depleted populations of Killer Whale (*Orcinus orca*), Humpback Whale (*Megaptera novaeangliae*), and Fin Whale (*Balaenoptera physalus*), and some populations of these species have become increasingly abundant and widespread in coastal waters in recent years (Ford *et al.* 2009, 2013, 2017; Nichol *et al.* 2018; Towers *et al.* 2015, 2018, 2019). Although the distribution and behaviour of less common cetacean species have been recorded (Ford 2014), the foraging ecology and habitat use patterns of some, such as Minke Whale (*Balaenoptera acutorostrata*), remain poorly understood.

Minke Whale is a small, migratory baleen whale that normally occurs in coastal waters of the eastern North Pacific between spring and fall (Towers *et al.* 2013). Despite a lack of human exploitation history in these waters, Minke Whales are relatively rare along the west coast of North America. Ship-based cetacean surveys between California and Washington have documented Minke Whales 18 times between 1991 and 2008 (Barlow and Forney 2007; Barlow 2010). Further north, in the coastal waters of British Columbia, surveys conducted by Williams and Thomas (2007) and Ford *et al.* (2010) detected only a combined total of 35 Minke Whales during 34 290 km of survey effort.

Directed photo-identification research on Minke Whales in British Columbia and Washington has also documented relatively few unique individuals with totals of only 38 identified between 1977 and 1987 (Dorsey *et al.* 1990) and 44 between 2005 and 2012 (Towers *et al.* 2013). Photo-identification data have not been compared between these periods, but at least one individual identified in the 1980s was also documented in the 2010s (J.R.T. unpubl. data). Several other individuals documented on more than one occasion show high degrees of inter- and intra-annual fidelity to certain coastal areas over long periods (Dorsey *et al.* 1990; Towers *et al.* 2013).

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The feeding behaviour of Minke Whales can be difficult to determine because most of it occurs below the water surface. However, in Washington, Minke Whales have been reported surface feeding on Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*) on 10 and two occasions, respectively (Hoelzel *et al.* 1989). Few data on Minke Whale prey have been reported in western Canada, but Minke Whales have also been observed lunge feeding at the surface around Cormorant Island off northeastern Vancouver Island (Towers *et al.* 2013).

The waters around Cormorant Island are relatively shallow compared to depths of other nearby waterways and the substrate is made up of glaciofluvial gravels and sand. Large tidal fluctuations (5 m) and varied bathymetry in this area result in strong currents (<10 km/h = <5 kts with anything over 2 kts generally considered to have an impact on the movements and behaviour of most commercial and recreational vessel traffic as well as most fish and marine mammals) and upwellings. These environmental variables combine to create favourable habitat for an array of marine species, including several cetaceans in addition to Minke Whales.

To study the behaviour and occurrence of these species non-invasively, we conducted systematic shore-based cetacean observations from Cormorant Island in the summer of 2012 while making concurrent underwater acoustic recordings. This note presents the visual results of this study combined with data from surface predation events by Minke Whales that were opportunistically documented from small research vessels around Cormorant Island from 2010 to 2014. The acoustic results of this study are reported in Nikolich and Towers (2018).

Visual observations of cetaceans were made from the north shore of Cormorant Island at 50°36.140′N, 126°56.820′W (Figure 1). Observers used naked eyes and 15 × 80 binoculars (Steiner, Greely, Colorado, USA) with built in magnetic (M) compass and reticle bar mounted on a leveled tripod (Velbon, Tokyo, Japan) to detect cetaceans over an arc of 160° (272°M–072°M). Visual surveys were conducted by two or more alternating observers for up to 13 h/day when Beaufort sea state levels were ≤2 (see http://www.wdcs.org/submissions_bin/WDCS_Shorewatch_Seastate.pdf for explanation of Beaufort sea

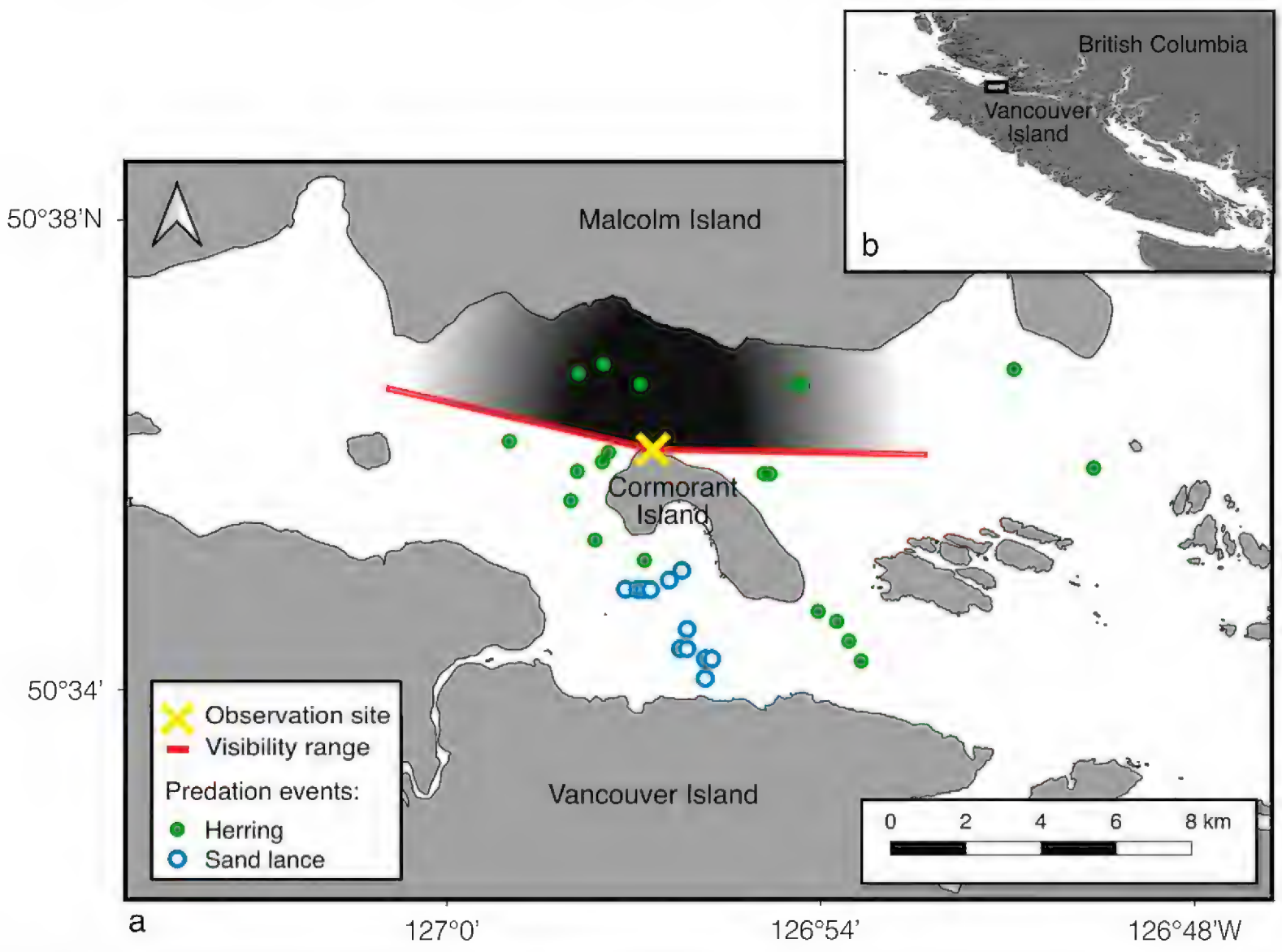

FIGURE 1. The study area off northeastern Vancouver Island, with a. showing the point on Cormorant Island from which observations were made, the arc of visibility, and the locations of Minke Whale (*Balaenoptera acutorostrata*) predation events and prey species documented from research vessels from 2010 to 2014 in relation to b. the south and central coasts of British Columbia.

states). Data, including Beaufort sea state, tide height, and notes on visibility, were recorded every 30 minutes of survey effort. The time, compass bearing, and reticle distance were recorded each time a cetacean surfaced (Nikolich and Towers 2018), but when Minke Whales and other species were present in the study area, priority was given to recording the surfacings of Minke Whales. The behaviour of cetaceans was noted when apparent, and an effort was made to identify individual whales visually when they were within range. Individual Minke Whale identifications were based on unique natural markings as described and shown in Towers (2011). To reduce any biases arising from animals being missed when sighting effort was focussed in another section of the study area, cetacean occurrence is portrayed in this paper as presence per unit effort (PPUE). A unit of effort was classified as 55–60 minutes of uninterrupted visual surveys and PPUE was defined as the number of effort units that the species was present divided by the total number of effort units.

Between 11 June and 15 August 2012, weather conditions allowed for observers to make shore-based visual surveys on 54 days: 20 in June, 19 in July, and 15 in August (Figure 2). In total, 513 units of visual survey effort were conducted. Seven species of cetaceans were documented: Minke Whale, Humpback Whale, Fin Whale, Bigg's Killer Whale (*Orcinus orca*; also known as West Coast Transient population), Dall's Porpoise (*Phocoenoides dalli*), Harbour Porpoise (*Phocoena phocoena*), and Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*; Figure 2). Minke Whales had the highest PPUE (0.44), as they were observed during 224 units of effort (Figure 2; Table 1). Six previously known and individually recognizable Minke Whales were visually identified (M001, M002, M003, M004, M006, and M022; Towers 2011). Harbour Porpoises were the second most commonly present species in the study area followed by Humpback Whales and Dall's Porpoises (Figure 2; Table 1). The species with the lowest PPUE was Fin Whale (Figure 2; Table 1). All species were documented transiting; although most species likely foraged at depth in the study area, only Minke Whales, Humpback Whales, and Bigg's Killer Whales were observed feeding at the surface. Bigg's Killer Whales were documented preying on a Dall's Porpoise on one occasion, and Minke and Humpback Whales were observed feeding on small schooling fish on 15 and two occasions, respectively. No relation between tidal activity and the foraging behaviour or occurrence of any species was detected.

Between 10 September 2010 and 7 August 2014, predation at the surface by Minke Whales around Cormorant Island was also opportunistically documented from small research vessels on 32 occasions (Figure 3; Table 2). Prey species were visually identified from photographs, video, or samples of remains collected near the surface with a dip-net after the feeding event. Of the predation events, 20 were on Pacific Herring and 12 were on Pacific Sand Lance (Figures 1 and 3; Table 2). Of the six photo-identified Minke Whales involved in these events (Table 2), five were visually documented during the shore-based component of this study.

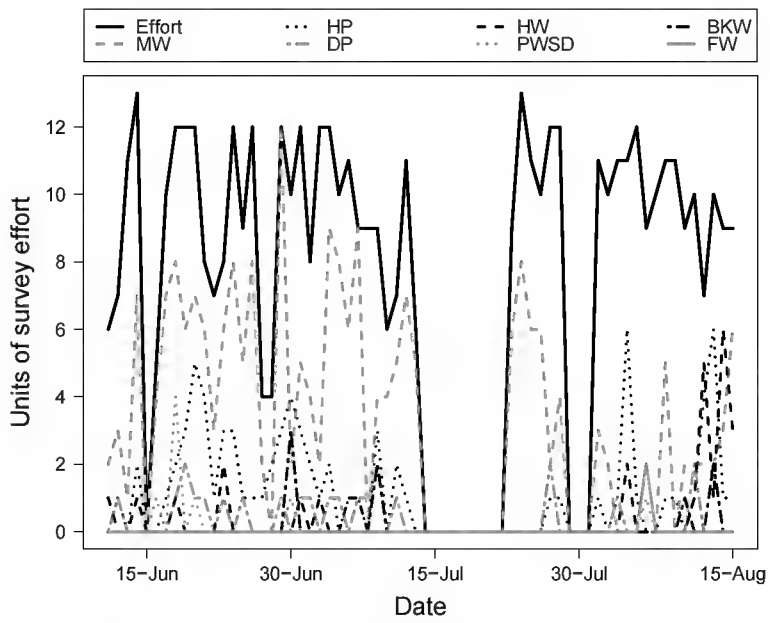

FIGURE 2. Units of survey effort and the presence per unit effort (PPUE) of each species of cetacean sighted between 11 June and 15 August 2012 off Cormorant Island, British Columbia. MW = Minke Whale (*Balaenoptera acutorostrata*), HP = Harbour Porpoise (*Phocoena phocoena*), HW = Humpback Whale (*Megaptera novaeangliae*), DP = Dall's Porpoise (*Phocoenoides dalli*), PWSD = Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), BKW = Bigg's Killer Whale (*Orcinus orca*), and FW = Fin Whale (*Balaenoptera physalus*).

TABLE 1. Occurence of cetaceans and presence per unit effort (PPUE) based on sightings from the north shore of Cormorant Island, British Columbia, 11 June to 15 August 2012.

	MW	HP	HW	DP	PWSD	BKW	FW
Days observed	45	39	14	20	5	4	1
Sightings	1551	109	113	35	23	40	3
Units present	224	80	27	23	8	8	2
PPUE	0.44	0.16	0.05	0.04	0.02	0.02	0

Note: BKW = Bigg's Killer Whale (*Orcinus orca*), DP = Dall's Porpoise (*Phocoenoides dalli*), FW = Fin Whale (*Balaenoptera physalus*), HP = Harbour Porpoise (*Phocoena phocoena*), HW = Humpback Whale (*Megaptera novaeangliae*), MW = Minke Whale (*Balaenoptera acutorostrata*), and PWSD = Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*).

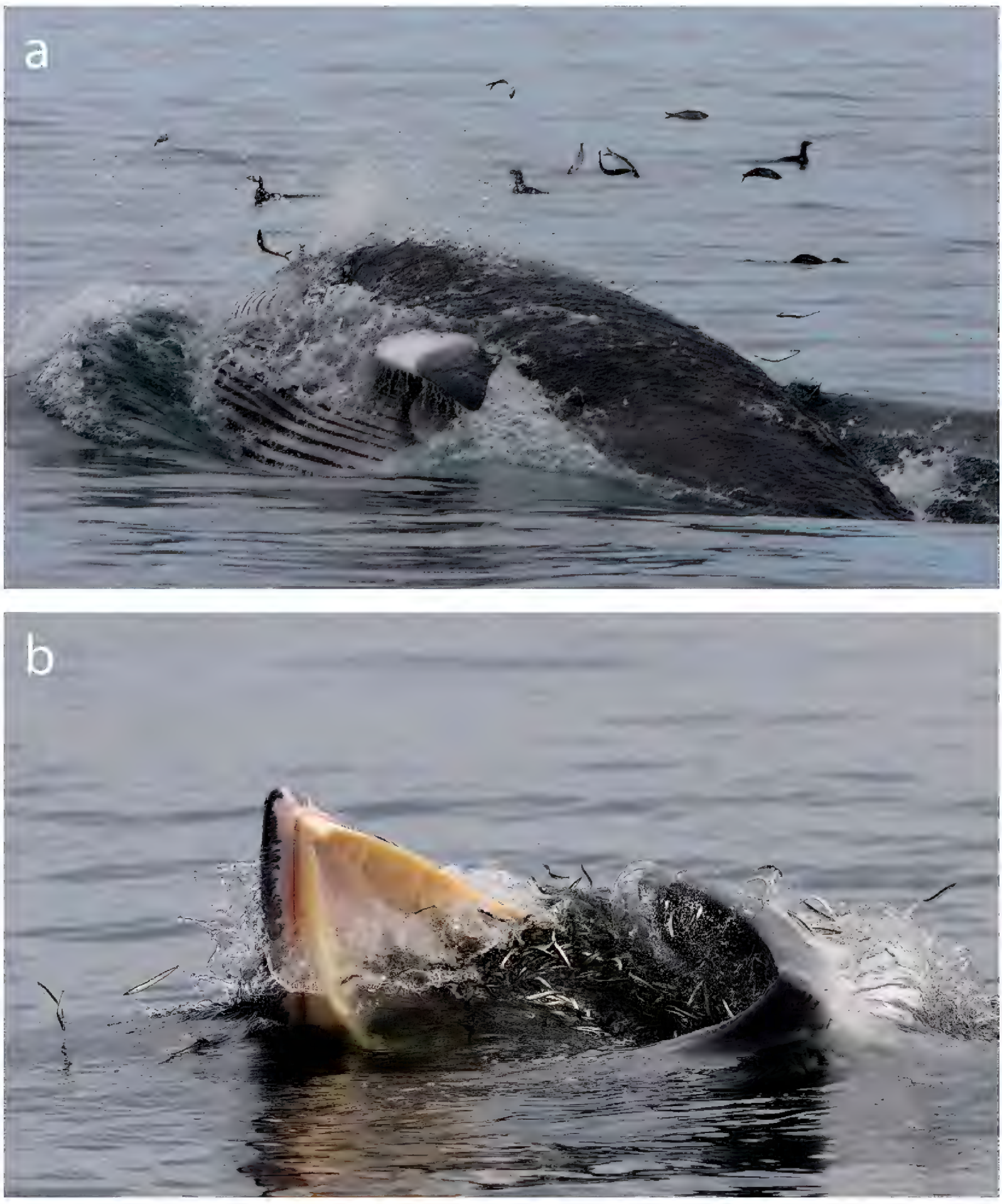

FIGURE 3. Minke Whale (*Balaenoptera acutorostrata*) M001 lunging on a. juvenile Pacific Herring (*Clupea pallasi)* on 18 July 2011 and b. juvenile Pacific Sand Lance (*Ammodytes personatus*) on 11 June 2014. Photos: Jared Towers.

Of the other species documented in this study, all but Bigg's Killer Whales are also known to feed on Pacific Herring (Walker *et al.* 1998; Morton 2000; Nichol *et al.* 2013; McMillan *et al.* 2018; Towers *et al.* 2018). Among them, at least the second, third, and fourth most commonly observed species in this study, Harbour Porpoise, Humpback Whale, and Dall's Porpoise also feed on Pacific Sand Lance (Walker *et al.* 1998; Nichol *et al.* 2013; Marine Education and Research Society unpubl. data). All species documented are relatively common in many coastal regions of the eastern North Pacific with the exception of Fin Whale. This species is rarely observed in the inshore waters around Vancouver Island and the individual

TABLE 2. Dates of foraging events by identified Minke Whales (*Balaenoptera acutorostrata*) around Cormorant Island, British Columbia, from 2010 to 2014, and prey species consumed: Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*).

Date	Individual whale	Prey species
10 Sep. 2010	M004	Pacific Herring
10 Sep. 2010	M006	Pacific Herring
18 Jul. 2011	M001	Pacific Herring
27 Jul. 2011	M006	Pacific Herring
1 Aug. 2011	M022	Pacific Herring
18 Sep. 2011	M007	Pacific Herring
18 Sep. 2011	M007	Pacific Herring
15 Jul. 2012	M001	Pacific Sand Lance
15 Jul. 2012	M004	Pacific Sand Lance
15 Jul. 2012	M001	Pacific Sand Lance
15 Jul. 2012	M002	Pacific Sand Lance
16 Jul. 2012	M001	Pacific Sand Lance
16 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
20 Jul. 2012	M022	Pacific Herring
25 Jul. 2012	M001	Pacific Herring
26 Aug. 2012	M006 or M004	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
11 Sep. 2013	M001	Pacific Herring
11 Jun. 2014	M001	Pacific Sand Lance
11 Jun. 2014	M001	Pacific Sand Lance
14 Jun. 2014	M006	Pacific Herring
1 Jul. 2014	M022	Pacific Herring
1 Jul. 2014	M022	Pacific Herring
31 Jul. 2014	M006	Pacific Herring
7 Aug. 2014	M001	Pacific Herring

observed is likely the same one photographed nearby the previous day as reported in Towers *et al.* (2018).

Although the species observed in this study are widely distributed throughout the eastern North Pacific (Ford 2014), the high rates of Minke Whale sightings compared with other cetacean species and numerous predation events recorded confirm this area as an important summer feeding ground for some individual Minke Whales that show intra- and inter-annual fidelity to these waters. To our knowledge, no other shore-based cetacean study in the eastern North Pacific has documented such high rates of Minke Whale occurrence, and the feeding observations reported here are among the first of this species in western Canada.

The environmental variables in the waters around Cormorant Island that create favourable habitat for Minke Whales and their prey are not unlike those documented in Minke Whale habitat in other regions. Minke Whale occurrence is positively correlated with shallow water that is near deeper water in Washington (Hoelzel *et al.* 1989) and Scotland (Robinson *et al.* 2009). The dynamic bottom topography of such areas often result in strong currents that drive upwelling and increase ocean productivity (Croll *et al.* 2005; Tynan *et al.* 2005). In addition, the sand and gravel substrate around Cormorant Island and in other areas where Minke Whales are often found in the western and eastern North Atlantic (Naud *et al.* 2003; MacLeod *et al.* 2004; Robinson *et al.* 2009; de Boer 2010) can provide suitable burrowing or rearing habitat for Minke Whale prey, such as Pacific Sand Lance (Bizzarro *et al.* 2016) and Pacific Herring (Hay and McCarter 2006), respectively. Further studies on Minke Whales off Cormorant Island could focus on relations between their occurrence and temporal fluctuations in the abundance and distribution of their prey and other environmental variables.

Author Contributions

Writing – Original Draft: J.T.; Writing – Review & Editing: J.T., C.M., and R.P.; Conceptualization: J.T.; Investigation: J.T., C.M., and R.P.; Methodology: J.T. and C.M.; Formal Analysis: J.T., C.M., and R.P.; Funding Acquisition: J.T.

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Use of salmon (*Oncorhynchus* spp.) by Brown Bears (*Ursus arctos*) in an Arctic, interior, montane environment

Mathew S. Sorum[1,*], Kyle Joly[1], and Matthew D. Cameron[1]

[1]National Park Service, Gates of the Arctic National Park and Preserve, 4175 Geist Road, Fairbanks, Alaska 99709 USA
[*]Corresponding author: mathew_sorum@nps.gov

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Abstract

Salmon (*Oncorhynchus* spp.) is a key dietary item for temperate coastal Brown Bears (*Ursus arctos*) across much of their circumpolar range. Brown Bears living in Arctic, interior, and montane environments without large annual runs of salmon tend to be smaller bodied and occur at much lower densities than coastal populations. We conducted ground and aerial surveys to assess whether Brown Bears fished for salmon above the Arctic Circle, in and around Gates of the Arctic National Park and Preserve. Here, we document the use of salmon by interior Brown Bears in the Arctic mountains of the central Brooks Range of Alaska. We believe our findings could be important for understanding the breadth of the species' diet across major biomes, as well as visitor safety in the park and Brown Bear conservation in the region.

Key words: Alaska; Brown Bear; diet; fishing; mountains; *Oncorhynchus* spp.; salmon; *Ursus arctos*; Brooks Range

Introduction

In temperate environments, Brown Bears (*Ursus arctos*) feed extensively on salmon (*Oncorhynchus* spp.; Hilderbrand *et al.* 1999a; Mowat and Heard 2006). The abundance of salmon in some river systems and their high nutritional value allow Brown Bears in these areas to grow much larger and live at much higher densities than Brown Bear populations without predictable access to seasonal marine resources (Hilderbrand *et al.* 1999a,b; Mowat and Heard 2006). For example, Brown Bears living in interior regions are often much smaller than coastal conspecifics and occur at much lower densities (Hildebrand *et al.* 2018a,b). Substantively lower resource availability is thought to be a major determinant of both body size and population density (Hilderbrand *et al.* 1999a,b; Mowat and Heard 2006). Bears use terrestrial protein sources (Caribou [*Rangifer tarandus*], Arctic Ground Squirrels [*Spermophilus parryii*], and Moose [*Alces americanus*]), as well as plants, nuts, and other foods when access to marine resources, such as salmon, is limited (Welch *et al.* 1997; Rode *et al.* 2001; Gau *et al.* 2002; Mowat and Heard 2006), in areas such as the Arctic, interior, montane environments of the central Brooks Range of Alaska.

Reports from local aircraft pilots of Brown Bears congregating along Arctic rivers during August and September have been received by the National Park Service (NPS) as early as 2008, although use of salmon by Brown Bears has never been reported in the central Brooks Range or in many other Arctic regions (e.g., MacHutchon and Wellwood 2003; Mowat and Heard 2006). In 2014, the NPS initiated a Brown Bear monitoring project. Global positioning system (GPS) data collected by that project indicated that Brown Bears in the interior mountains of the Brooks Range did indeed spend extended periods along larger river corridors from July through September.

Our goal was to document the timing and location of salmon use by Brown Bears in the central Brooks Range by direct observation. A better understanding of Brown Bear resource use in the region could be useful in determining the breadth of the species' diet across major biomes, as well as locally, for visitor management and Brown Bear conservation.

Methods

We conducted a survey of Brown Bears fishing in and around Gates of the Arctic National Park and Preserve (GANPP; Figure 1). GANPP encompasses an interior Arctic ecosystem characterized by the mountainous terrain of the Brooks Range, extensive spruce (*Picea* spp.) forests and lowland riparian areas on the range's southern flanks, and tundra on its northern side (Wilson *et al.* 2014). The headwaters of three major river systems begin in GANPP:

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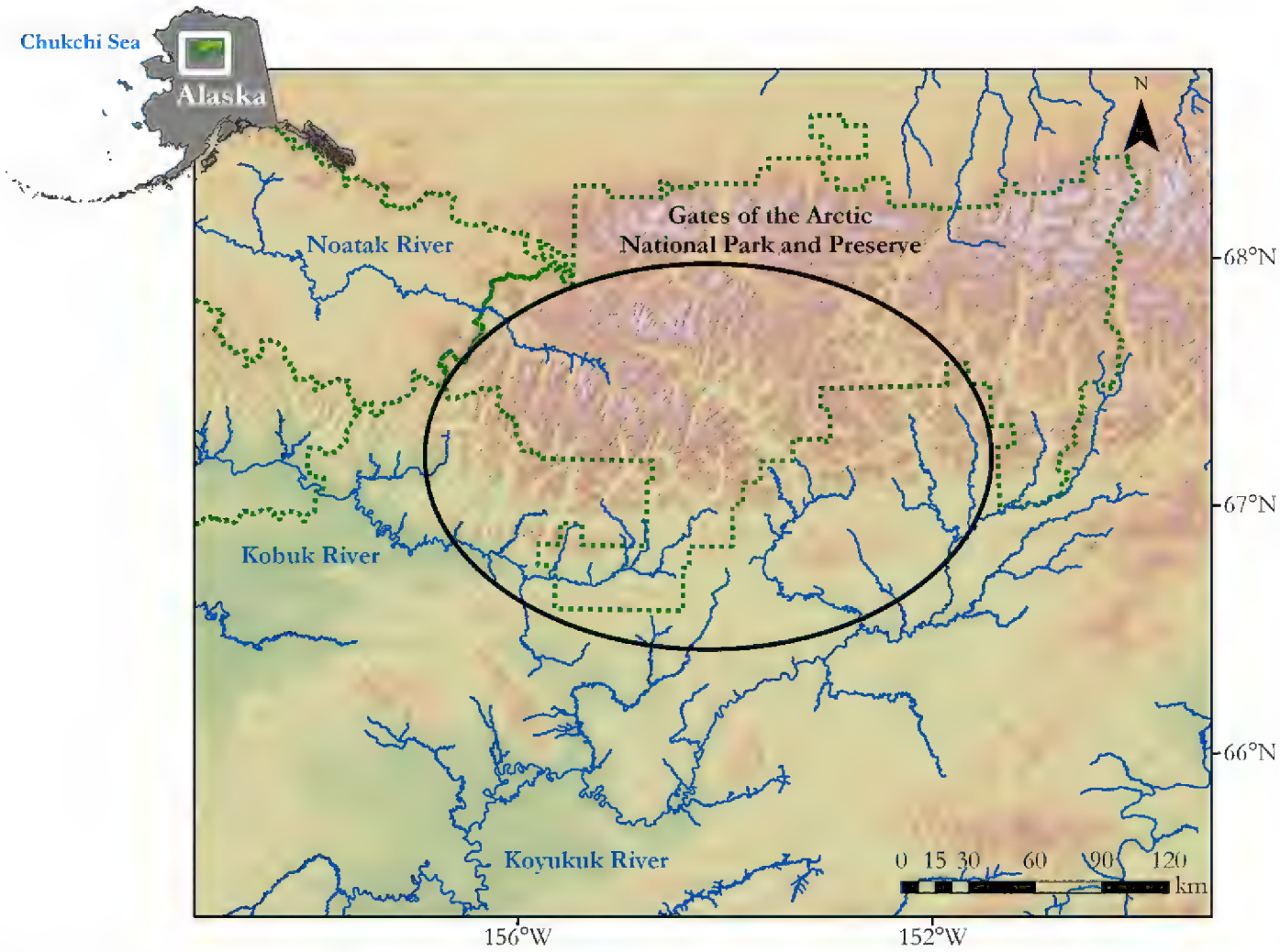

FIGURE 1. Study area (black oval) in the central Brooks Range mountains in Arctic Alaska.

the Kobuk, Koyukuk, and Noatak rivers. The Kobuk River drains west about 550 km (river length) to the Chukchi Sea (part of the Arctic Ocean) with most of the major tributaries arising in the southern Brooks Range. The Koyukuk River, a major tributary of the Yukon River, drains southwest for 1870 river-km from GANPP to the Bering Sea. The Noatak River drains northwest about 660 river-km to the Chukchi Sea, with all of its major tributaries arising in the northern Brooks Range.

Site-specific salmon escapement numbers are not available for our study areas, as these counts usually focus on commercial fisheries in salt water and specific freshwater streams important for sport or subsistence fishing. However, each of GANPP's three main rivers has runs of Chum Salmon (*Oncorhynchus keta*) and Chinook Salmon (*Oncorhynchus tshawytscha*) from mid-July to early September (O'Brien and Berkgiler 2005).

We visited one tributary in each of GANPP's three main river systems to document use of salmon by Brown Bears in the region. The specific locations visited were determined from GPS collared bears (n = 33) or reports by pilots and were accessible by wheeled or float plane. (For more information about our collaring efforts, which were in accordance with the guidelines of the American Society of Mammalogists [Sikes and Gannon 2011] and approved by United States Geological Survey and NPS Institutional Animal Care and Use Committees [IACUCs; 2014-1 and 2014A2, respectively], see Hilderbrand *et al.* 2018a.)

In 2016, we surveyed 8 km of the Kobuk River system (Table 1). In 2017, we surveyed 2 km of the Noatak River system and 8 km of the Koyukuk River system (Table 1). Our surveys involved walking along river banks and/or floating down streams in a raft to identify signs of bears fishing (e.g., fish carcass, scat, or observations of bears fishing) and document the presence of salmon species. Along the Noatak River system, we used a vantage point above an area that we suspected bears used for fishing to look for bears using a 20 × 60 spotting scope.

Results

During each stream visit, we observed bears fishing or identified recent signs of fishing activity (i.e., salmon gill plate, mandible, carcass, or bear scat with fish remains in it; Table 1). On the Kobuk River system, 17 August 2016, we found a large pile of fresh gill plates (Figure 2) along a sharp bend in the river where a deep pool had formed. Although we did not observe a bear fishing, we surmised that bears were diving for the salmon carcasses that we observed lying at the bottom of the pool.

On the Koyukuk River system, 2 August 2017, we observed an adult male fishing by "snorkeling" upstream in ~1.5 m of water and another adult male fish-

TABLE 1. Observations of Brown Bears (*Ursus arctos*) using salmon (*Oncorhynchus* spp.) in the central Brooks Range, Alaska, 2016–2017.

River system	Observation	Dates	Notes
Kobuk	Salmon gill plates	17 August 2016	Fresh pile of plates found adjacent to a deep pool formed at bend in river
	Fresh bear tracks	1–4, 17, 29 August 2016 9–10 September 2016	Single bears and family groups
	1 bear*	29 August 2016	Adult fishing near Chum Salmon
Koyukuk	1 bear*	4 August 2016	Adult fishing near Chum Salmon
	1 male bear	2 August 2017	Large male snorkeling upstream in 1.5 m of water
	1 male bear	2 August 2017	Large male fishing along a shallow side stream
	1 male bear	21 August 2017	Large male fishing along a shallow portion of river
	Salmon gill plates	22 August 2017	Fresh pile of plates found along bank of river
Noatak	3 bears	28 July 2017	A Brown Bear family group fishing at the confluence
	11 bears	29 August 2017	8 independent bears and 1 sow with 2 2-year-old cubs fishing along 2 km of river
	1 male bear	30 August 2017	Male bear fishing along a shallow side stream

*Aerial survey; all other observations were made during ground-based surveys.

ing along a shallow (<0.5 m) portion of the stream.

On 29 August 2017, we spent 4 h observing bears fishing from a vantage point above the Noatak River. We observed 11 bears (eight independent adults and one female with two 2-year-old cubs) using ~2 km of stream. Each adult was observed catching at least one salmon. Most bears either walked upstream along the bank or in the stream to locate and catch spawning Chum Salmon (Figure 3). All bears fished along a small (<250 m) section of stream and were often close to other bears.

We also documented the presence and spawning activity of Chum Salmon at each stream.

FIGURE 2. Salmon remains (jaws and gill plates) found along a tributary of the Koyukuk River, Alaska, 22 August 2017. Piles such as these were common along well-worn game trails at the river edge. Photo: Matthew Cameron, National Park Service.

Discussion

Our surveys substantiate earlier reports that interior, montane Brown Bears in the Arctic fish for salmon. Although the Brown Bears we studied lived about 400 km inland (or 550–1800 river-km from the coast), Chum Salmon were present and used by Brown Bears. Our findings build on past research that evaluated broad diet patterns of Brown Bears across North America (Mowat and Heard 2006). Even though salmon occur in streams throughout the Brooks Range, Mowat and Heard (2006) reported no use of salmon by Brown Bears in the central Brooks Range. Our observations of Brown Bears fishing for salmon across multiple river systems throughout the central Brooks Range provide evidence that salmon are not only used by bears here, but are likely an important seasonal food resource in the region.

Many interior populations of Brown Bears rely solely on terrestrial food resources, such as green vegetation, berries, and ungulates to satisfy their nutritional requirements (Gau *et al.* 2002; MacHutchon and Wellwood 2003; Mowat and Heard 2006). However, if available, some interior bear populations consume salmon (Belant *et al.* 2006). In the Arctic interior, food is even more limited for bears, as the growing season is short and ungulate densities are quite low and sparsely distributed over vast areas (Gasaway *et al.* 1992). Thus, where salmon resources are available, they likely play an important dietary role for bears living in the Arctic interior and may alter their distribution, body size, and population density (Hilderbrand *et al.* 1999a; Deacy *et al.* 2016, 2019).

FIGURE 3. A Brown Bear (*Ursus arctos*) successfully acquiring a salmon (*Oncorhynchus* spp.) from a tributary of the Noatak River, central Brooks Range Alaska, 30 August 2017. Photo: Mathew Sorum, National Park Service.

Consumption of salmon by Brown Bears provides a direct avenue for nutrient and energy transfers from marine to lotic to terrestrial systems (Hilderbrand *et al.* 1999c). Inputs of marine-derived nutrients into a terrestrial system creates cascading effects across trophic levels via increased productivity (Mathewson *et al.* 2003; Winder *et al.* 2005), and the effects are likely compounded in a nutrient-limited system, such as GANPP. Ultimately, this relationship creates biological hotspots with higher productivity, species diversity, and richness (Naiman *et al.* 2002). Identification of these areas is important for conservation and preservation of these important ecological systems. For example, areas of congregating Brown Bears in this low-density system may warrant additional hunting and/or visitation restrictions in the future to avoid overhunting and/or disturbance during the critical period of hyperphagia.

Identification and further elucidation of the relation between salmon and bears in interior ecosystems will improve the understanding and management of population dynamics of both predators and their prey. Future research should consider estimating the composition of salmon in the diet of Brown Bears and the influence of salmon on seasonal distribution and habitat selection patterns of bears.

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Note

Roman Snail, *Helix pomatia* (Mollusca: Helicidae), in Canada

Robert G. Forsyth[1,*], and James Kamstra[2]

[1]New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[2]AECOM, 105 Commerce Valley Drive West, Markham, Ontario L3T 7W3 Canada
*Corresponding author: rforsyth.bc.ca@gmail.com

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Abstract

Populations of Roman Snail, *Helix pomatia*, a large European land snail, are reported for the first time in Canada from disturbed habitats in two distant locations: Sarnia, Ontario and Montrose, British Columbia. As Roman Snail is an edible species subject to international commercial trade, its deliberate, but illegal, introduction into Canada and intentional or unintentional releases are possible sources of these populations.

Key words: Mollusca; terrestrial snail; gastropod; new provincial records; Ontario; British Columbia; biogeography

The genus *Helix* L., 1758, in its modern, restricted sense, is a group of large-bodied land snails of Europe, some parts of western Asia, and North Africa (Schileyko 2006; Mumladze *et al.* 2008; Fiorentino *et al.* 2016). Larger land snails, including species of the genus *Helix* and its type species, *Helix pomatia* L., 1758 (Figure 1), are among those that have been consumed by humans for millennia (Bar 1977; Lubell 2004).

The range of *H. pomatia*, Roman or Burgundy Snail, includes central and southern Europe, but also extends into western and northwestern Europe to coastal areas of countries on the Baltic Sea and west to France and England (Kerney 1999; Neubert 2013, 2014), with the ancestral range in the Balkan region (Fiorentino *et al.* 2016). The presence of this species in Britain is generally believed to represent a Roman introduction (Taylor 1910; Kerney 1966, 1999); the Romans went so far as importing, breeding, and rearing snails in "cochlearia" (Taylor 1900). The original geographic range of *H. pomatia* may have been central European, with its spread into western Europe a result of ancient introductions by humans (Taylor 1910).

Recently, introductions have been reported as far east as European Russia (Sysoev and Schileyko 2009; Egorov 2015). In the United States, perhaps the first established population was noted in Jackson, Michigan, in 1937 (Archer 1937; Pilsbry 1939), but *H. pomatia* is now also known from Wisconsin, New York, Massachusetts, Indiana, Pennsylvania, Florida, and California (GBIF 2017; NatureServe 2019). The presence of this species in Canada has gone unreported in the literature, and we document here the occurrence of *H. pomatia* in British Columbia and Ontario.

Specimens were collected opportunistically by us or our contacts and are vouchered in the Mollusc Collection of the New Brunswick Museum, Saint John (NBM). Shell height (H) and diameter (or width; D) of unbroken, apparently mature specimens were measured using a digital caliper, to the nearest 0.1 mm.

Helix pomatia was first observed at Canatara Park in Sarnia, Ontario, on 10 May 2013 by J.K. (Figure 1a). Three live specimens and one empty shell were collected on 31 May 2013. Canatara is a multi-use municipal park of ~80 ha that is surrounded by urban lands. The south portion (~25 ha), where Roman Snails were found, was once a landfill site, which has regenerated over many decades. It consists of old field, thickets, and woodland with a high proportion of non-native invasive plant species. Roman Snails were found in dry meadow co-dominated by goldenrods (*Solidago* sp.) and Canada Thistle (*Cirsium arvense* (L.) Scopoli) with some Garlic Mustard (*Alliaria petiolata* (M. Bieberstein) Cavara & Grande). The snails were often seen under debris, such as boards, or climbing on vegetation up to 30 cm above the ground. The non-native, European Grove Snail, *Cepaea nemoralis* (L., 1758), was abundant in Canatara Park.

At Montrose, British Columbia (BC), S. Munch (pers. comm. 2015) had observed *H. pomatia* on his property since moving there in 2002. The habi-

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FIGURE 1. Roman Snail, *Helix pomatia*. a. Canatara Park, Sarnia, Ontario. b. Shells from Sarnia, Ontario (left; NBM 010198) and Montrose, British Columbia (right; NBM 010200). Photo: a. J. Kamstra. Photo: b. R. Forsyth.

tat is an open area that includes lawn and tall uncut grass with small Trembling Aspen (*Populus tremuloides* Michaux), spruce (*Picea* A. Dietrich sp.), and Western Red Cedar (*Thuja plicata* Donn ex D. Don). The maximum number of snails encountered at one time was 15–20 individuals in a 9 × 9 m area.

We are also aware that *H. pomatia* has persisted for several years at Revelstoke, BC (H. Douglas pers. comm. 2014), but have little information about its presence there.

No native or introduced land snail in Canada approaches the size of *H. pomatia*, which is one of the largest of the European *Helix* species (up to 50 mm; Kerney and Cameron 1979). The only other established, large helicid species in Canada is Brown Gardensnail, *Cornu aspersum* (Müller, 1774), more commonly known as *Helix aspersa,* but that species is easily recognized by its smaller shell, different pattern of shell pigmentation, and different sculpture, among other characters (Kerney and Cameron 1979). *Helix lucorum* L., 1758, which can grow to be larger than *H. pomatia*, might be confused with *H. pomatia*, although it has markedly more prominent banding. Indeed, Burke (2013) figured a specimen of *H. lucorum* that he misidentified as *H. pomatia.*

Based on our own observations and correspondence with the discoverer of the Montrose population of *H. pomatia*, we believe that both this and the Sarnia population have persisted for several years (at least 13 years at Montrose) and that this species can be added to the growing list of introduced terrestrial molluscs in Canada. Variation in shell sizes suggests that different generations exist.

Throughout its range in Europe, *H. pomatia* inhabits milder coastal areas as well as mountainous regions with more continental climates. Thus, the suc-

cessful establishment of this species in Canada is not a surprise. However, as climate change brings milder winters, in the future, we might expect increasingly more successful introductions of terrestrial molluscs in different parts of the country. Novel records of introduced terrestrial molluscs in Canada continue to be discovered, even in areas that are rather well explored (e.g., Forsyth 1999, 2008; Reise *et al.* 2000; Forsyth *et al.* 2001, 2016; Maunder *et al.* 2017). The discovery of *H. pomatia* at Montrose and Revelstoke adds a second introduced snail species known from the BC interior but not from the milder south coast region of BC. More surveys for terrestrial molluscs around populated centres, such as those of Forsyth (1999) who focussed on the Vancouver and Victoria regions, would be useful in the BC interior. Similar to BC, southern Ontario has been rather well explored for terrestrial snails. The great extent of modified habitats there allows for the foothold of many synanthropic, introduced species. The possible invasiveness of *H. pomatia* is not known. Apparently the species persists but had not spread far from Jackson, Michigan, even 80 years after it was first discovered (Atkinson 2019). At the Sarnia site, the species has not become appreciably more abundant in the five years since it was first discovered, in contrast to the highly invasive *Cepaea nemoralis*.

Most non-native terrestrial snails and slugs are likely accidentally introduced with plants, soil, and debris, or movements of other materials. However, for *H. pomatia*, the source of the introductions is uncertain. It seems likely that someone raising Roman Snail deliberately or unintentionally released several individuals. Roman Snail is an edible species that has international commercial value and is sold for both food and the pet trade. It is listed for sale on various websites, such as My Happy Snails (https://www.myhappysnails.com/), based in Ukraine, which will ship abroad to willing buyers. It is possible that Roman Snail was deliberately imported into Canada, although the importing of any species of *Helix* into Canada is prohibited (D. Mooij pers. comm. 2019). The Sarnia location is only about 150 km from where *H. pomatia* occurs in Michigan, but it seems unlikely that the Sarnia snails originated from that location, given the presence of an international border, a water barrier, and the distance.

Voucher specimens

Canada: Ontario: Lambton County: Sarnia: Canatara Park: ca. 43.0°N, 82.4°W, *leg.* James Kamstra, 31 May 2013 (NBM 010198, 1 specimen). British Columbia: Kootenay-Boundary Regional District: Montrose, ca. 49.1°N, 117.6°W, *leg.* Steven Munch, summer and fall 2015 (NBM 010200, 33 specimens; Figure 1b). British Columbia: Columbia-Shuswap Regional District: Revelstoke, 12 June 2014 (NBM 010199, 1 specimen).

Canadian shells (Figure 1a) can be described as follows. The shell is large (H = 33.6–42.0 mm, D = 30.46–39.37 mm; mean H/D = 1.05, SD = 0.05, n = 27) and rather globular with a conical spire. It is pale grey-brown, with lighter and darker colabral streaks and, in general, two to five spiral bands, which are sometimes rather weakly marked or absent. There are ~4 convex whorls, with the last whorl descending in full-grown specimens. The periphery is rounded, medial on the last whorl. The protoconch is smooth. The teleoconch has irregular, low, somewhat riblet-like colabral ridges and spiral rows of weak granules. The aperture is large, subovate-rounded, and showing the external shell colour through the shell wall. The outer lip is scarcely thickened and narrowly outwardly flared. The columellar lip is pinkish-brown, expanded, and almost sealing the umbilicus, which is a narrow slit.

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First record of Paintedhand Mudbug (*Lacunicambarus polychromatus*) in Ontario and Canada and the significance of iNaturalist in making new discoveries

Colin D. Jones[1,*], Mael G. Glon[2], Karen Cedar[3], Steven M. Paiero[4], Paul D. Pratt[3], and Thomas J. Preney[3]

[1]Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, 300 Water Street, Peterborough, Ontario K9J 3C7 Canada
[2]Department of Evolution, Ecology, and Organismal Biology, Ohio State University, 318 West 12th Avenue, Columbus, Ohio 43210 USA
[3]Ojibway Nature Centre, 5200 Matchette Road, Windsor, Ontario N9C 4E8 Canada
[4]University of Guelph, School of Environmental Sciences, 50 Stone Road East, Guelph, Ontario N1G 2W1 Canada
[*]Corresponding author: colin.jones@ontario.ca

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Abstract

Paintedhand Mudbug (*Lacunicambarus polychromatus* (Thoma, Jezerinac & Simon 2005)) (Decapoda: Cambaridae) was recently discovered at three locations in Windsor, Ontario. These represent the first reports of this burrowing crayfish in Canada. iNaturalist, a nature app and website designed to record photo-based observations of plants and animals, was instrumental in facilitating this discovery. We discuss the importance of collaborative platforms, such as iNaturalist, for linking naturalists and citizen scientists to taxonomic experts around the globe.

Key words: Cambaridae; crayfish; Decapoda; iNaturalist; *Lacunicambarus polychromatus*; new distribution record; Ontario; Paintedhand Mudbug

Introduction

Paintedhand Mudbug (*Lacunicambarus polychromatus*) is a burrowing crayfish in the family Cambaridae that was newly described in 2005 (Thoma *et al.* 2005). Until recently, it was included in the genus *Cambarus* Erichson, 1846, in the rejected subgenus *Tubericambarus* Jezerinac, 1993 (Crandall and De Grave 2017). Phylogenetic analyses of mitochondrial DNA (mtDNA) sequence data combined with morphological and ecological characteristics have, however, indicated that *L. polychromatus* and several closely related species of burrowing crayfish are monophyletic and distinct from *Cambarus* (Glon *et al.* 2018). As a result, the subgenus *Lacunicambarus* Hobbs, 1969 has been resurrected and redescribed at the generic level to accommodate them (Glon *et al.* 2018).

Lacunicambarus polychromatus is known from throughout much of the North American midwest east of the Mississippi River (with the exception of a recent record from Missouri; Missouri Statewide Historical Crayfish Database 2019), as well as parts of Kentucky and Tennessee (see Figure 2 in Thoma *et al.* 2005). Throughout its range, *L. polychromatus* is commonly found in burrows in low-lying habitats close to the water table, including the banks and floodplains of lakes and rivers, roadside ditches, and wetlands (Thoma *et al.* 2005). The recent recognition of *L. polychromatus*, stemming in part from historical confusion with the closely related Devil Crayfish (*Lacunicambarus diogenes*), has led to a relative paucity of correctly identified records of this species in museum collections and databases. The full extent of the range of *L. polychromatus*, therefore, remains undetermined, and no records of this species have been reported previously from Canada.

Methods

On 26 May 2017, members of the Committee on the Status of Species at Risk in Ontario (COSSARO) visited the Ojibway Prairie Provincial Nature Reserve (42.263°N, 83.071°W) in Windsor, Ontario, along with several staff from the Ontario Ministry of Natural Resources and Forestry and the Ojibway Nature Centre, City of Windsor. During the visit,

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a large adult burrowing crayfish was encountered above ground during the daytime. The individual was photographed and the photos (Figure 1) were uploaded to iNaturalist (see https://inaturalist.ca/observations/6501788), a web-based application designed to capture and share photo-based records of plants and animals. At the time of the observation, the crayfish was identified as *L.* aff. *diogenes* (see Glon *et al.* 2018), a species known to occur in Ontario, Canada (Crocker and Barr 1968; Guiasu *et al.* 1996; Hamr 1998). Six months later, the iNaturalist record was discovered by M.G.G., an expert on the taxonomy of *Lacunicambarus* currently working on revising the genus, who suspected that it was more likely to be *L. polychromatus*. Additional photos were uploaded to the record allowing for confirmation that the species was indeed *L. polychromatus*, a species not previously reported for Canada.

On 15 May 2018, C.D.J. and M.G.G. returned to the original location to conduct additional surveys for the species and to collect a voucher specimen and tissue samples for DNA analysis. Burrows were searched for in ditches and along watercourses, and a hand-pumping technique, which included pouring additional water into the burrows, was used to bring the crayfish to the surface. Surveys for burrowing crayfish were also conducted on the same day at four additional locations in the Windsor area (Figure 2, Table 1). When burrows were located, the technique described above was used to extract crayfish. Voucher specimens were collected at each location where crayfish were found and have been deposited at the Royal Ontario Museum, Toronto, Ontario. A tissue sample was also taken from the Ojibway Prairie specimen for mtDNA sequencing.

Results

The surveys on 15 May 2018 at Ojibway Prairie Provincial Nature Reserve were successful in confirming the presence of *L. polychromatus*. At this location, burrows were found along a shallow ditch running along the northern edge of the nature reserve not far from where the specimen was located in 2017. The nature reserve is 105 ha in size and includes a

FIGURE 1. Paintedhand Mudbug (*Lacunicambarus polychromatus*) recorded on 26 May 2017 at Ojibway Prairie Provincial Nature Reserve, Windsor, Ontario. Distinguishing characteristics of the species are indicated by lines: closed areola (a, c); deflected rostrum (b1); suborbital angle (b2); dorsal surface of the palm of the chela with mesial quarter to third studded with tubercles not forming distinct rows (d). Photos: Colin D. Jones.

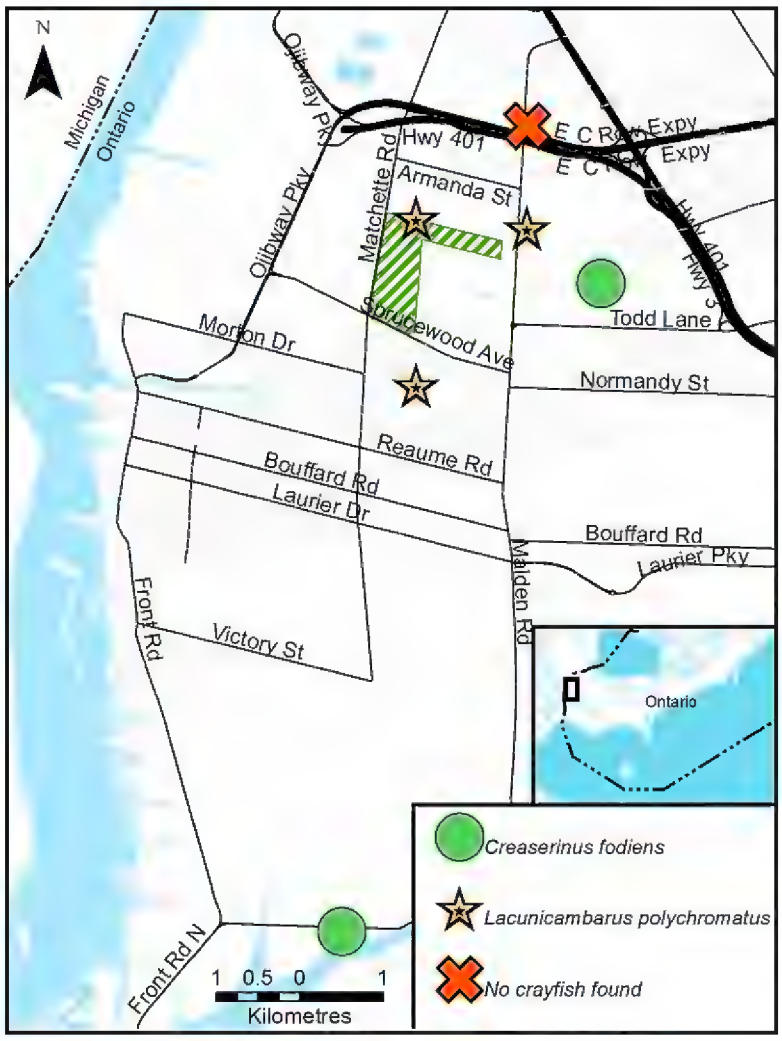

FIGURE 2. The six survey sites in the Windsor, Ontario, area. Stars indicate the three locations where Paintedhand Mudbug (*Lacunicambarus polychromatus*) was detected. Circles indicate the two locations where Digger Crayfish (*Creaserinus fodiens*) was found. The × indicates a location where no crayfish burrows or crayfish were found. The hatched area represents the Ojibway Prairie Provincial Nature Reserve.

combination of native tallgrass prairie and prairie/savanna habitat. It is part of a complex of closely situated natural areas located in the City of Windsor that together protect nearly 350 ha of native prairie, savanna, and forest.

A single specimen of *L. polychromatus* was collected, preserved in 95% ethanol and deposited at the Royal Ontario Museum (ROMIZ L5261). The GenBank accession numbers for 12S (MH878691), 16S (MH878723), and partial CO1 (MH882991) have been previously reported in Glon *et al.* (2019).

On the same day, *L. polychromatus* was also collected from a nearby site, Vince Marcotte Park (42.245°N, 83.071°W). Unlike the natural habitat of the nature reserve, the burrows at Vince Marcotte Park were located on the manicured lawn of the park bordering Turkey Creek. There were many burrows at this location and two specimens of *L. polychromatus* were collected and deposited at the Royal Ontario Museum (Table 1, Figure 2).

On 15 May 2018, three additional sites were surveyed (Table 1). At one site, no crayfish burrows were located. At the other two sites, crayfish burrows were found and hand-pumped. The species present, however, was Digger Crayfish (*Creaserinus fodiens*), which was first discovered in Ontario, Canada, in 1863 and is often found living in burrows adjacent to those of *L. polychromatus* in the United States (Cottle 1863; Hobbs 1974).

Following the discovery that *L. polychromatus* occurs in the Windsor area (Table 1), an additional photo-based record was uploaded to iNaturalist from a third location adjacent to Ojibway Prairie. An individual was found by Steve Marks above ground, at night, and backdated to 24 May 2016 (see https://inaturalist.ca/observations/17855665). The location is a residential yard bordered by a shallow drainage ditch adjacent to a dry-moist old field. Crayfish burrows are periodically found in the manicured lawn and along the banks of the ditch at this location, but no attempts have been made to survey for crayfish.

Discussion

The Ojibway Prairie complex in extreme southwestern Ontario supports a number of plant and animal species that are restricted to this unique portion of the province, not to mention the entire country (Oldham 1992; Paiero *et al.* 2010; Pratt 2018). The discovery of *L. polychromatus* here represents the first record of the species in Canada. The closest known occurrences are in adjacent Michigan, where it has been known since it was first described (Thoma *et al.* 2005); thus, it is not entirely surprising that it was eventually recorded across the Detroit River in the Windsor area. *Lacunicambarus polychromatus* is almost certainly native to Canada, rather than being a recent colonizer or introduction, and its presence has likely gone undetected because of historical confusion about the taxonomy of *Lacunicambarus*. Additional surveys will be required throughout southwestern Ontario to delineate the full extent of the species' range in Canada. We also suggest that preserved specimens ascribed to "*C. diogenes*" (i.e., *L.* aff. *diogenes*) be re-examined, particularly if they were collected before *L. polychromatus* was described in 2005, to determine if the latter species is more widely distributed in Ontario than the observations documented herein led us to believe. Such information will also be critical in making an accurate assessment of the species' conservation status provincially and nationally.

Lacunicambarus polychromatus can be differentiated from all other Canadian crayfishes by its closed areola (Figure 1a,c); strongly deflected rostrum (in lateral view; Figure 1b1); presence of a suborbital angle (Figure 1b2); Form I male gonopods with two terminal elements directed caudally at approxi-

TABLE 1. Records of Paintedhand Mudbug (*Lacunicambarus polychromatus*) from Ontario, Canada, including locations where the species was searched for unsuccessfully. Repositories include both iNaturalist (for photo-based records) and the Royal Ontario Musuem (ROM). Catalog numbers for iNaturalist refer to the unique record number and are accessible online by adding the catalog number to the end of the URL, https://inaturalist.ca/observations/.

Date	Location	Latitude, °N	Longitude, °W	Habitat	Details	Observers	Repository	Catalog no.
24 May 2016	Lambton St., Windsor	42.262	83.059	Suburban yard bordering drainage ditch	Incidental; one *L. polychromatus* photographed	S.M.	iNaturalist	17855665
26 May 2017	Ojibway Prairie Provincial Nature Reserve, Windsor	42.263	83.071	Native tallgrass prairie	Incidental; one *L. polychromatus* photographed	C.D.J., M.G.G., K.C., S.M.P., P.D.P., T.J.P., + COSSARO members	iNaturalist	6501788
15 May 2018	Ojibway Prairie Provincial Nature Reserve, Windsor	42.263	83.071	Shallow ditch bordering native tallgrass prairie	Targetted search; burrows detected and pumped; one *L. polychromatus* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5261 12590089
15 May 2018	Vince Marcotte Park, Windsor	42.245	83.071	Urban park lawn bordering creek	Targetted search; burrows detected and pumped; two *L. polychromatus* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5262 ROMIZ L5263 12590307
15 May 2018	Continental Ave., Windsor	42.273	83.059	Roadside ditch bordering small field in industrial area	Targetted search; no burrows or crayfish detected	M.G.G., C.D.J.	n/a	n/a
15 May 2018	Spring Garden Natural Area, Windsor	42.256	83.051	Wooded swamp	Targetted search; burrows detected and pumped; one *Creaserinus fodiens* (Digger Crayfish) collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5265 12590235
15 May 2018	River Canard Park, Amherstburg	42.186	83.079	Roadside ditch bordering recreational park	Targetted search; burrows detected and pumped; one *Creaserinus fodiens* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5264 12590320

mately 90° relative to the gonopod shaft, the distal most of which (central projection) is markedly shorter than the proximal one (mesial process); and dorsal surface of the palm of the chela with mesial quarter to third studded with tubercles not forming distinct rows (Figure 1d). Although colouration is subject to variation and is not always a reliable character, *L. polychromatus* typically exhibits striking orange and red highlights along its rostral margins, chelae, and the dorsoposterior margins of its abdominal somites and blue or green shades across its body (Figure 1a–d). This crayfish is almost always collected from burrows, but it is occasionally encountered in open waters or even on land, particularly after heavy rain. Burrows with recent activity have fresh mud at the opening (Figure 3) often forming a chimney (Figure 4). The burrows themselves are not, however, diagnostic to species, and there are several species of burrowing crayfish.

iNaturalist was instrumental in facilitating the discovery of this species in Canada. Had it not been for iNaturalist, its presence may have remained undetected. As iNaturalist grows in popularity, more and more amateur naturalists and citizen scientists are uploading their photos and seeking confirmation of their identification. For example, in the 10 years since its inception in 2008 over 7 000 000 observations have been contributed by 224 334 users (iNaturalist 2019). In 2018 alone, the total number of observations more than doubled to well over 15 000 000 and the number of users also more than doubled to an astonishing 501 308 (iNaturalist 2019; also see Martin 2018 for a summary of Canadian records). At the same time, more and more taxonomic experts are becoming involved in iNaturalist by offering their expertise at providing or correcting identifications. This was certainly the case with the Ojibway Prairie record of *L. polychromatus* that would have been entered in field notes and potentially in databases as a record of *L.* aff. *diogenes*. In time, the photos may have been re-examined and re-determined as *L. polychromatus*, but iNaturalist has provided a platform that has greatly increased the ability of amateurs and experts to collaborate in real time. This collaboration is greatly increasing our collective knowledge of the distribution and, in fact, the conservation status of species.

There are other examples of this rapid increase in species discoveries. In Ontario alone, for example, at least 40 species of moths new to the province (at least 19 of which are new to Canada and one new to North America) have been discovered (M.V.B. Burrell pers. comm. 22 January 2019) through iNaturalist submissions since the recent publication of a comprehensive annotated Canadian Lepidoptera list (Pohl *et al.* 2018).

As species, such as Paintedhand Mudbug, are newly discovered in Ontario, they are added to the provincial species list maintained by the Natural Heritage Information Centre (NHIC), Ontario Ministry of Natural Resources and Forestry, and are assigned a conservation status rank following methods developed by NatureServe (Faber-Langendoen *et al.* 2012; Master *et al.* 2012). Paintedhand Mudbug has been assigned a rank of S1S2 (critically imperilled to imperilled). The NHIC typically compiles observations of species with a conservation status rank of S3 (vulnerable) or higher. These observations then inform areas of conservation value (element occurrences) and are added to the provincial record where they are available to inform conservation, land-use, and natural resources management planning, policy, and legislation.

iNaturalist is also greatly increasing the ability to detect the introduction of exotic and potentially invasive species. A new and potentially invasive vascular plant species, Small-flowered Jewelweed (*Impatiens parviflora* de Candolle), for example, has been

FIGURE 3. Fresh mud at the opening of a crayfish burrow in Vince Marcotte Park, Windsor, Ontario, Canada (42.245°N, 83.071°W), 15 May 2018. Photo: Colin D. Jones.

FIGURE 4. A Paintedhand Mudbug (*Lacunicambarus polychromatus*) chimney in Muhlenberg County, Kentucky, USA (37.313°N, 87.201°W), 11 June 2018. Photo: Mael G. Glon.

recently documented in Ontario through iNaturalist (Oldham 2018).

The growth and popularity of iNaturalist is not showing any signs of slowing down. With such growth, an increasing number of local, regional, and national discoveries will be made, such as the discovery of *L. polychromatus* in Canada. Such discoveries will assist in advancing our collective knowledge of the distribution and conservation status of species. The NHIC has created a project on iNaturalist that users can join allowing their personal observations of provincially rare species to be considered for incorporation into the provincial record (https://inaturalist.ca/projects/nhic-rare-species-of-ontario).

Author Contributions

Writing – Original Draft: C.D.J. and M.G.G.; Writing – Review and Editing: all; Conceptualization – C.D.J. and M.G.G.; Methods – M.G.G. and C.D.J.; Investigation – all.

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Note

Duckling mortality at a river weir

Stewart B. Rood[1,*] and Amber Willcocks[1]

[1]Department of Biological Sciences, University of Lethbridge, Lethbridge, Alberta T1K 3M4 Canada
[*]Corresponding author: rood@uleth.ca

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Abstract

River weirs are low-head dams that dissipate energy by creating hydraulic recirculation zones at their base. These recirculation zones are a major cause of human drownings and have been referred to as "drowning machines". We observed an event that allowed us to add ducklings to the list of weir victims. As a Mallard (*Anas platyrhynchos*) hen and her brood floated over the Calgary weir, the mother flew safely over the hydraulic recirculation. The ducklings drifted into the recirculation and three quickly passed through; four were stalled, repeatedly recirculated, and died. We observed other regional weirs where adult birds commonly flew over the hazard. We did not observe any other waterfowl drifting into recirculation zones, and we found no prior report of this lethal hazard. Although mortality might be rare at each weir, with hundreds of thousands of low-head dams worldwide, the collective hazard could be substantial. Weirs can be designed to eliminate the lethal recirculation zone, and the apparent hazard to ducklings could provide another motivation to redesign or modify these common structures.

Key words: Bow River; dams; mortality; waterfowl

Human developments impose many lethal challenges on wildlife. Avian mortality can follow collisions with windows, towers, power lines, airplanes, or wind turbines (Weir 1976; Avery *et al.* 1980). Alterations to streams, ponds, and lakes impose additional challenges for waterfowl, including the flooding of nests and increased predator access (Mauser *et al.* 1994; Flint and Grant 1997). We are investigating the ecological consequences of weirs and other river dams (Rood *et al.* 2003, 2010) and observed another, apparently unreported, cause of waterfowl mortality.

Our observation was from the viewing platform at the weir across the Bow River in Calgary, Canada (Figure 1; 51°2.61′N, 114°0.85′W). This weir creates an elevated head pond upstream, which allows for offstream water diversion for irrigation. The concrete weir produces a drop of about 2 m into the stilling pool, forming a hydraulic recirculation zone, which is also referred to as a "hydraulic jump" or "hole" (Figure 2; Makuk 1988; Bradshaw 2004). This recirculation zone dissipates energy to reduce erosion of the weir base and downstream channel. Because of the recirculation, buoyant objects that float over the sill are often stalled in the trough, and are retained there or plunge down into the seam created by falling water. These objects flow slightly downstream, then resurface because of their buoyancy while still within the turbulent recirculation zone. This imposes a repetitive and somewhat violent cycle, and the recirculation zone can thus be retentive, as revealed with sticks, logs, and a wheel in the trough of the Calgary weir (Figures 1 and 3).

With the hydraulic recirculation, low-head dams will often stop swimmers or stall and capsize small boats, and then recirculate the victims. The lethal hazard of these "drowning machines" is well recognized, as human drownings at river weirs continue to represent about a fifth of recent North American river fatalities (Walbridge 2000; Bradshaw 2004). The Calgary weir has been especially lethal, with at least 10 fatalities from 1982 through 2007, including four double drownings (Makuk 1988; Canadian River Safety 2019). Largely because of the drowning hazard, this weir was modified in about 2010 to divide the single major drop into a sequence of smaller irregular drops, eliminating the retentive hydraulic recirculation zone and creating the safer Harvie Passage paddling park.

While at that construction site on 4 June 2009, we observed a fatal wildlife incident. Near mid-day, a

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FIGURE 1. The Calgary weir in June 2009 (discharge 109 m^3/s), displaying the river water flowing over the weir and into the hazardous hydraulic recirculation zone, with trapped sticks and a wheel. The structure on the far side allows offstream diversion into an irrigation canal. This system was subsequently modified with the Harvie Passage to produce safer paddling channels. Photo: Stewart Rood.

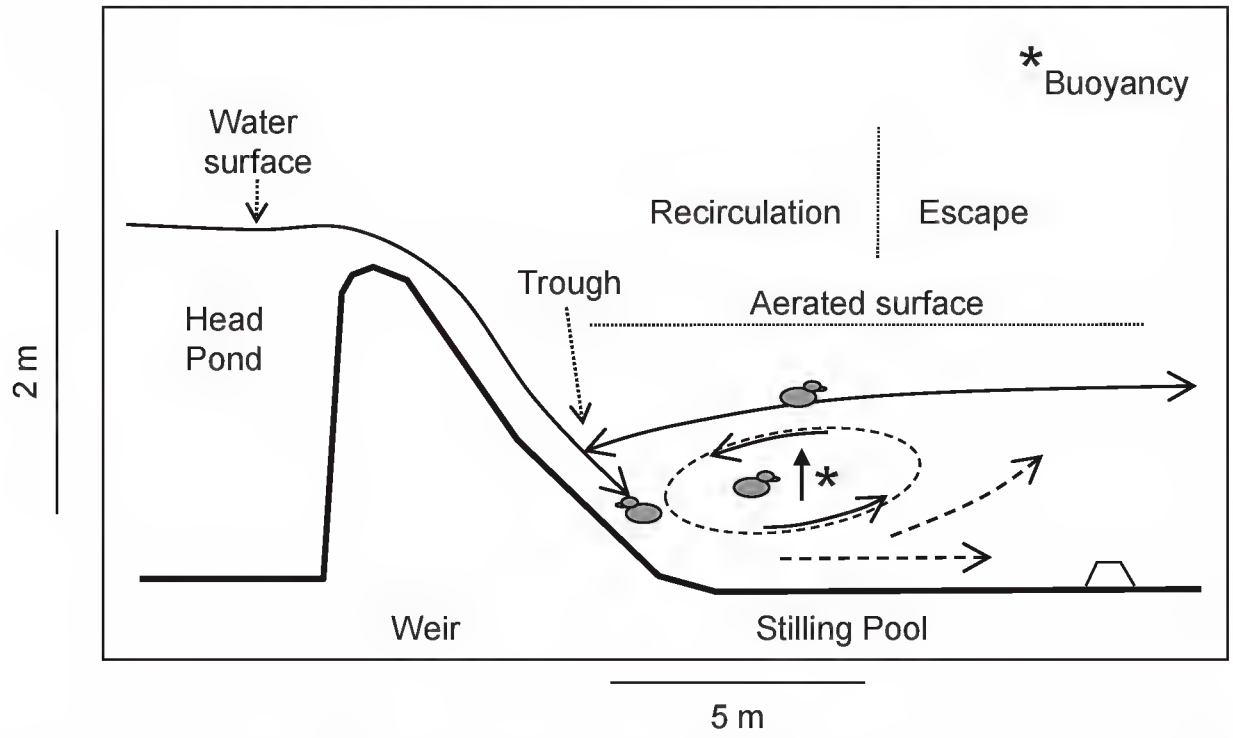

FIGURE 2. A cross-section of the Calgary weir and hydraulic recirculation zone with scaling based on Makuk (1988) and Golder (2002). The positions of the submerged ducklings are based on flume simulations with objects of similar buoyancy and observed emergence patterns. Note the exaggerated vertical scale.

Mallard (*Anas platyrhynchos*) hen and her brood of seven ducklings drifted slowly along the south bank (Figure 3). As water flowed over the weir, the ducklings turned upstream and appeared to paddle vigorously. As the hen floated over the sill, she rose with a few wing strokes and glided downstream beyond the recirculation zone. Some of the ducklings turned toward her and paddled vigorously downstream.

Paddling into the trough, three passed through fairly quickly, apparently aided by a break in the recirculation because of a tumbling log in the trough. The other four ducklings were stalled. Each was plunged down, and we observed three of the four resurface a few seconds later in the aerated surface, 3–4 m downstream. Despite paddling downstream, each was drawn back upstream into the trough and

FIGURE 3. A Mallard (*Anas platyrhynchos*) hen with seven ducklings approaching the hydraulic recirculation zone at the Calgary weir, 4 June 2009. Three of these ducklings survived, while four died. The hen is just rising and subsequently flew over the recirculation area. Photo: Stewart Rood.

again plunged under water. With each recirculation, the ducklings appeared to be weakened as they became less vigorous. We observed two ducklings recirculating three times and one four times, but did not observe the fourth over the next few minutes. After about five more minutes, one duckling emerging in the water downstream from the hydraulic recirculation area, drifting passively on its side, apparently dead. We observed no further evidence of the remaining three ducklings over an additional 30 min.

This incident demonstrates that a low-head dam can be lethal for ducklings. The mature hen was readily able to fly over the retentive hydraulic recirculation zone, but the ducklings were unable to fly and were, therefore, vulnerable. Of the seven ducklings, four apparently died, indicating that this powerful recirculation was quite hazardous.

This physical hazard from low-head dams may be very common; the design of these dams is fairly universal and consistently produces retentive and lethal hydraulic recirculation zones (Makuk 1988; Walbridge 2000; Bradshaw 2004). There are about 45 000 large dams world-wide (World Commission on Dams 2000) and low-head dams are probably about ten-fold more numerous (Chandler and Chapman 2003; Doyle *et al.* 2003). With this widespread occurrence and the apparent lethality for ducklings, we conclude that weirs could provide a substantial hazard for juvenile waterfowl.

To investigate whether this hazard is recognized in the field of ecology, we conducted Google Scholar and Web of Science literature searches with search term combinations including duck, duckling, mortality, death, hazard, dam, and weir. These revealed extensive reports on duckling mortality, including reviews and bibliographies, showing that duckling mortality is considerable (Ringleman and Longcore 1982; Savard *et al.* 1991; Flint and Grand 1997), largely as a result of predation (Talent *et al.* 1983; Mauser *et al.* 1994). Although many reports of hazards to waterfowl and other birds from various types of artificial structures exist (Weir 1976; Avery *et al.* 1980), we found no reference to the drowning hazard from river weirs. Wildlife biologists with Alberta Environment and Parks reported that they had never seen ducklings or goslings drifting over weirs, but were not surprised by the possibility, because waterfowl are abundant in head ponds above weirs in southern Alberta.

News and social media websites were another source of information. A Google search (September 2019) on "ducklings and weirs" revealed YouTube, Facebook, and news media videos, photographs, and

reports of ducklings unable to follow the mother hen up and over weirs or stranded in troughs or drains below weirs. These ducklings were uninjured and were often assisted by observers or wildlife officers; for some repetitive cases, screens or other measures solved the stranding. We found no report of ducklings retained, injured, or killed in the hydraulic recirculation zone of a river weir.

Over five years, we visited other river weirs, including the 1-m-high Lethbridge Northern Irrigation District weir (49°39.9′N, 113°36.1′W), the 1.5-m City of Lethbridge weir on the Oldman River (49°40.9′N, 112°51.4′W), and the 3-m Carseland weir on the Bow River (50°49.5′N, 113°26.6′W). These weirs also produce retentive hydraulic recirculation zones and humans have drowned at the Lethbridge and Carseland weirs (Canadian River Safety 2019). We undertook 50, 6-hour observer-days at these three weirs during June from 2010 through 2015.

During these observations, water birds were common near each of the weirs, including the piscivorous American White Pelican (*Pelecanus erythrorhynchos*) and Double-crested Cormorant (*Phalarocorax auritus*). In addition to Mallards, other ducks were abundant, including Common Merganser (*Mergus merganser*), Common Goldeneye (*Bucephala clangula*), occasional Wood Ducks (*Aix sponsa*), and other species. Canada Goose (*Branta canadensis*), including goslings, were also abundant, along with Ring-billed (*Larus delawarensis*) and other gulls. We commonly observed adults drifting toward the weirs, and they would consistently fly before drifting into the hydraulic recirculation zone. Ducklings or goslings were common, but we did not see any others drift over the weirs; thus, it is probably uncommon for waterfowl to drift into recirculation zones. We have repeatedly observed pelicans and some other birds fishing right below and even in the recirculation zone during summer intervals when river flows are lower and the hydraulic power and hazard are probably slight (Figure 4).

Following these observations, we suspect that the hazard to waterfowl varies considerably across weirs and with different river flows. A small weir on a small stream would produce a modest hydraulic recirculation zone that would be less capable of stopping and recirculating ducklings. The hydraulic force and hazard would increase with increasing drop height and stream discharge. The Carseland weir hydraulic system was very loud and this may have signaled its presence from 100 m or more upstream. Waterfowl were abundant in the upstream pond, but remained well away from that drop. With the reduced hazard of smaller weirs and noise cues of larger weirs,

FIGURE 4. The Lethbridge weir across the Oldman River in late summer when flows are low and the recirculation hazard is reduced. American White Pelicans (*Pelecanus erythrorhynchos*) are common, feeding on fish that are blocked by the weir from upstream passage. Photo: Stewart Rood.

it is possible that intermediate-sized weirs, such as the Calgary weir, might provide the greatest risk to ducklings.

The lack of prior reporting of duckling deaths in weir recirculation zones could indicate that this source of mortality is rare. Conversely, the lack of evidence may reflect ducklings' inconspicuous nature. Ducklings are small and cryptic, and hens encourage secretive behaviour (Mauser *et al.* 1994). Also, reducing the likelihood of observation, humans are discouraged from approaching river weirs by signage or fencing. Although stilling pools, the slow flowing zones downstream of weirs, are sometimes favoured for fishing, this is less common during the interval of turbid water and high flow rates in late spring and early summer, when ducklings are unable to fly and thus more vulnerable.

Although the extent of mortality is unknown, the prospective drowning hazard to waterfowl could provide one more reason to avoid weir designs that create "drowning machines". In addition, modifications to existing weirs to eliminate the hydraulic recirculation zone should reduce the risk for ducklings and possibly other wildlife, as well as humans. For example, the modifications to the Calgary weir to create the safer Harvie Passage might reduce future duckling mortality at this location where we observed the tragic drownings in 2009.

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Book Reviews

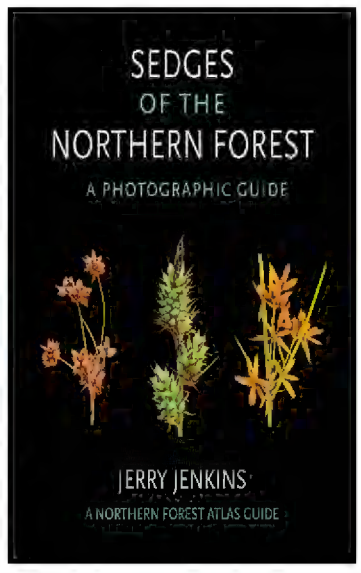
Book Review Editor's Note: *The Canadian Field Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes: CAD Canadian Dollars, USD United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

Botany

Sedges of the Northern Forest: A Photographic Guide

By Jerry Jenkins. 2019. Cornell University Press. 96 pages, 16.95 USD, Paper.



Another regional guide to identification of sedges (Cyperaceae) has been published, this time covering the species found in what has been referred to as the "Northern Forest". This book—and it's companion "Quick Guide", a boxed set of two fold-out charts—joins several other excellent treatments of sedges from various parts of North America that have been published in recent years. The area covered by this book does not include much of the forest region Canadians generally would think of as "northern", which would be the boreal forest; rather, it covers mainly what we think of as the Great Lakes–St. Lawrence Forest Region in Ontario and Quebec, and the Acadian Forest Region in the Maritime Provinces (Rowe 1972).

As the title indicates, this book is a photographic guide. It is laid out in such a way that comparisons among similar species can be made easily. The use of a black background behind the images assists greatly in highlighting the important features, such as shape of the perigynium, venation on the perigynium surface, perigynium beak shape, size, and orientation, overall inflorescence and individual spike morphology, scale shape, colour, and size, and various other features that are critical for identification. The great majority of the species found in the region are included with photographs, but there are a few species for which only brief mention is made in the text that supplements the photographs; most of the species without photographs are rare, range-edge species within the region covered.

The book begins with a brief introduction explaining its role and ways to use it. This is followed by an illustrated glossary, the illustrations being simplified caricatures or outlines of the features being described. Throughout the book, some simple symbols and abbreviations are used to assist in interpretation of structures, such as symbols for the sex of the individual flowers or spikelets, and the cross-sectional shape of the achenes. A helpful section on vegetative features, arrangement of spikelets within the larger inflorescence, achene shapes, perianth bristles, etc. is followed by a quick guide to the genera found in the flora, the latter again accompanied by stylized illustrations. Then, the detailed treatment of genera and the sections and species within them (in *Carex*, for example) follows. All genera, and in the case of *Carex*, sections within the genus, are treated alphabetically. Following this, a section called "Quick Guides to *Carex*" provides more details on morphology of spikelets, including arrangement of the sexes within them, perigynia, achenes, and, to a lesser extent, leaf and sheath features. Short paragraphs supplement the photographs in this section and provide additional hints on identification including, where applicable, habitat notes. More detail on each species is found later in the text, but this section provides a quick reference to help in narrowing down which group within *Carex* a specimen belongs.

Almost half of the book is dedicated to photographs of the most important features that aid in the

identification of individual species. Generally, the photographs focus on inflorescence, spikelet, flower, and achene features, but occasionally also include vegetative features. Key features are noted with the photographs (e.g., solitary spikelet, stems smooth, base of bract with lobes), and there are also paragraphs for each genus, section, or group of similar species highlighting distinctive features or providing brief notes on habitat preferences. The quality of the images generally is very good and the notes are helpful. In most cases, the photographs selected for inclusion convey a good representation of the characteristic appearance of the species. For difficult groups such as *Carex* section *Ovales*, a nice job has been done of grouping similar species together on the plates (e.g., species with perigynia >2 mm wide, species with perigynia covered by the scales). Another difficult group, the genus *Eleocharis*, has also been dealt with quite well, with good images and notes. One exception to the representation of species with typical photographs is the image of the upper part of the inflorescence of *Carex molesta*, which does not convey its typical appearance, at least to my eye. The spikelets usually are more closely aggregated into a cluster. Another exception is the inflorescence of *Carex lenticularis*, which normally shows a striking pattern of pale green perigynia among bicoloured black and green scales within the spikelets.

I did detect a number of typographical and formatting errors in the text, such as an incorrect symbol beside the inflorescence of *Carex exilis*, lack of italics here and there, the odd missing letter in a word, duplicated entries in the list of older names on p. 87, errors with the listing of *Carex appalachica* and *Carex radiata* in the list of older names, and so on, but in general the text and the plates are well put together. The author has included his own opinions on topics such as the flurry of nomenclatural changes that has occurred with *Carex* sectional names over the past few decades, the distinctness (or not) of certain species (e.g., *Carex tincta*), and similarities among unrelated species, all of which add some colour to the text. One such comment that has me scratching my head, though, is his perception that *Carex capillaris* is somewhat similar to *Carex eburnea*. Nevertheless, the great majority of the text contributes well to assisting the user to identify sedges.

Overall, this book is well conceived, and provides an excellent resource for field botanists who wish to get a better handle on the identification of species in this large and diverse family in the northeastern USA and southeastern Canada. Although the size is a bit cumbersome, I think that it could still be opened on a desk next to a specimen or adjacent to a dissecting scope and used effectively. I certainly recommend it field botanists and naturalists interested in improving their knowledge of this important family of flowering plants.

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WILLIAM J. CRINS

Peterborough, ON, Canada

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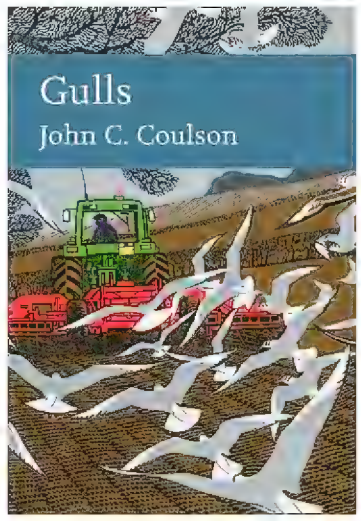
ORNITHOLOGY

Gulls

John C. Coulson. 2019. New Naturalist Library, HarperCollins Publishers. 495 pages, 108 charts and graphs, 35 maps, and 109 colour pictures, 135.99 CAD, Cloth.



This book is about the gulls of Great Britain and Ireland and to a lesser extent those of Western Europe, but it includes many generalisations that apply to gulls everywhere, gulls being a relatively uniform group of birds. A 42-page overview chapter deals with the taxonomy, biogeography, demography, plumage variation, and breeding biology within the Laridae. This is followed by comprehensive individual accounts for the nine species breeding regularly in Britain (about 25 pages each, but 64 on Black-legged Kittiwake [*Rissa tridactyla*]) and by chapters on rare species (17), on methods used to study gulls, on urban gulls (considered a big problem in Britain), and on conservation and management. There is a "selected bibliography" that is certainly sufficient to satisfy all but the most demanding reader (a full bibliography was considered too extensive to be included) and a few statistical appendices, as well as one dealing with the taxonomy of the Herring Gull (*Larus argentatus*) complex in Europe.

Compared to a similar area of Canada, Britain is relatively rich in gulls: only five species breed in the Maritimes, for instance. In addition, there has been a great deal of research on British gulls, especially Herring Gull, Lesser Black-backed Gull (*Larus fuscus*), and Black-legged Kittiwake. Consequently, the author has a lot of material to work with. Moreover, a substantial proportion of it was actually amassed by Coulson and his students (including Canadians John Chardine and Julie Porter) over a span of nearly 70 years. This is the summary of a lifetime's work by a very industrious and distinguished (and long-lived) scientist!

In his Foreword, Coulson mentions an early interest in banding. This seems to have continued because the book includes many maps of band recoveries and movements figure prominently in the species accounts. Where the author has researched the species extensively (Herring Gull, Black-legged Kittiwake) he gives many details from personal field experience. These anecdotes are among the most enlightening in the book. The methods chapter devotes several pages to banding as a research technique and includes a description of how the author discovered and developed the use of Darvic to make colour-fast plastic bands. This material is still used in many avian studies worldwide and has been an important component of my own research on auks. For many years, the Canadian Wildlife Service sourced its colour bands from John Coulson's technician at Durham University!

The book, printed in China, is nicely produced on glossy paper with excellent maps, charts, and photographs. John Coulson was a pioneer in the study of seabirds, especially long-term population studies. He was the source for many methods still current in the field. He writes with the authority appropriate to his seniority and lifetime of research. Yes, the accounts are a little parochial: we do know something about Herring Gulls and Black-legged Kittiwakes in North America, but Coulson makes no pretence that these are other than United Kingdom-based accounts. Despite its slightly narrow focus, *Gulls* is a must for anyone interested in any branch of Ornithology.

TONY GASTON

Ottawa, ON, Canada

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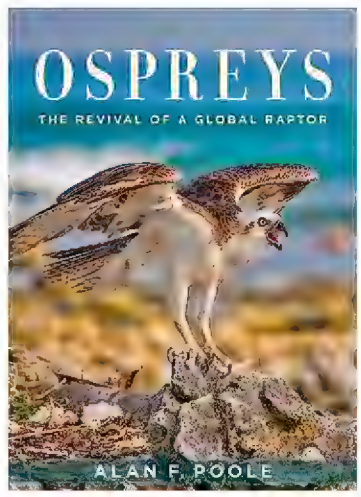
Ospreys: The Revival of a Global Raptor

By Alan F. Poole. 2019. John Hopkins University Press. 205 pages, 39.95 USD, Cloth or E-book.



Many of us are familiar with the catastrophic declines in Bald Eagle (*Haliaeetus leucocephalus*) and Peregrine Falcon (*Falco peregrinus*) populations owing to DDT and their subsequent recovery in at least parts of their ranges. But many may not be aware of the extent to which Osprey (*Pandion halieatus*) were similarly affected. Alan Poole is clearly an authority on the subject, having studied Ospreys in New England for over 35 years and authoring numerous scientific publications on the subject.

The title of this new offering is a bit of a misnomer, however, as the book covers a lot more ground than just the recovery of the species. An initial Introduction sets the stage and "A Hawk that Fishes" (Chapter 2) describes the Osprey's morphological adaptions, including differences among subspecies. The "Geography of Ospreys" (Chapter 3) summarizes the status of different Osprey populations across its global range, including Canada (citing several provincial atlassing efforts). Subsequent chapters cover foraging ecology, nesting behaviour, and migration, with the final two chapters discussing threats and solutions and the future outlook for Osprey. With such a cosmopolitan species and the breadth of topics he touches upon, Poole has done an admirable job constructing a cohesive narrative.

Poole's new book also brings into the discussion technological advances such as satellite telemetry, geolocators, and DNA evidence that have helped further our understanding of Ospreys over the last 30 years. Clearly willing to share the credit, he includes sidebar profiles on other Osprey researchers—reminding us how it takes a global village to understand this wide-ranging raptor. He also mentions where our understanding of Osprey is lacking, such as the period when young Osprey are learning to forage and during their first migration. I would like to have learned what factors exclude Osprey from breeding in tropical South America and Africa, given they overwinter there and reside year-round in Australia—but perhaps that will have to wait for Poole's next book.

Scientific chops notwithstanding, Poole's very readable prose makes it accessible for the layperson despite the quantity of information presented. For example, when discussing Osprey learning to fly, he remarks "As any human pilot will tell you – flying is easy; it's the landings that are tough" (p. 104) and mentions how human mothers with a houseful of rowdy teenagers might sympathize with female Ospreys at the nest. The book also benefits from over 100 excellent, decent-sized photographs and illustrations of Ospreys and their habitats, covering all manner of behaviour. Well laid-out maps showing Osprey movement patterns (from telemetry data) and several charts add to the fantastic visuals. On a very minor note, it would have been informative to have a density map of breeding Osprey in North America, but perhaps there are insufficient data. More Canadian content (and calling Nunavut a territory rather than a province on p. 44) would also have been welcome, but I suppose one can only ask so much with a global raptor. I do wish however, that all species names be capitalized or none; for example, Osprey is capitalized but Black Caiman and Agami Heron are not (p. 133).

My first childhood encounter with Ospreys was watching one catch a fish in a northern Ontario lake, only to see it lost to a marauding Bald Eagle. Since then, despite being a professional biologist, I have learned woefully little about this remarkable raptor. *Ospreys: The Revival of a Global Raptor* has greatly helped me address such gross negligence. I thoroughly enjoyed reading it and would highly recommend it to both novice naturalist and experienced birder alike.

ROBERT F. FOSTER

Northern Bioscience, Thunder Bay, ON, Canada

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ZOOLOGY

The New Beachcomber's Guide to the Pacific Northwest

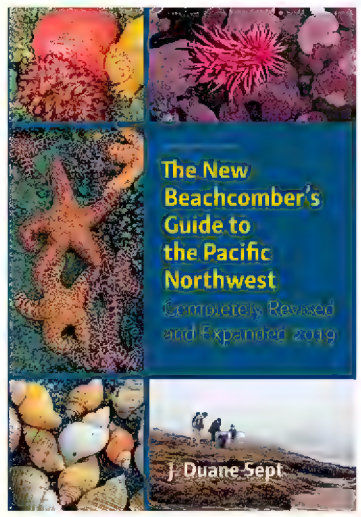
By J. Duane Sept. 2019. Harbour Publishing. 432 pages and 880 photographs, 32.95 CAD, Paper.

A Field Guide to Marine Life of the Protected Waters of the Salish Sea

By Rick M. Harbo. 2019. Harbour Publishing. Pamphlet, 7.95 CAD, Folding Guide.

A Field Guide to Marine Life of the Outer Coasts of the Salish Sea and Beyond

By Rick M. Harbo. 2019. Harbour Publishing. Pamphlet, 7.95 CAD, Folding Guide.



My recent move from Ontario to British Columbia (BC) introduced me to a number of new environs, each with their own suite of organisms. Mountains, glaciers, and temperate rainforests were all new to me. Perhaps most exciting of all were my first encounters with shoreline and intertidal life on the Pacific Ocean. Being more acquainted with the Carolinian Forest and Great Lakes shores, I was unable to identify most of what I saw. This similar situation must present itself to many who visit Canada's Pacific Coast or the United States' Pacific Northwest for the first time.

A series of new field guides, all by the same BC-based publisher, aim to provide a quick introduction to the species found on the shorelines and beaches of BC and the Pacific Northwest. Two different formats are employed. The first is a full field guide: *The New Beachcomber's Guide to the Pacific Northwest* by J. Duane Sept. This compact but hefty softcover book gives a detailed introduction to life in the intertidal zone. A brief opening chapter explains tides, shoreline zones, and microhabitats within the coastal ecosystem. What follows is 300+ pages of accounts of the most common invertebrate, algae, lichen, and plant species to be found on the beach. Each species is given one or two full colour photographs, a common name, scientific name, and brief outline of range, physical description, and life history notes. Species accounts proceed taxonomically with sections on sponges; anemones, hydroids, and jellies; comb jellies; worms; molluscs; lampshells; arthropods; bryozoans; echinoderms; tunicates; fish; seaweeds; plants; and lichens. No keys or identification guides are provided, so the book is best used by flipping through to find a photo that looks most like the strange creature you just found under a rock. For easier comparison, full colour plates of a range of limpets, snails, bivalves, and urchins are provided separately. This book is big, certainly bigger than a back pocket, but will likely provide greater chance of identification for those that must know about everything they find.

Parallel to, but separate from, this approach are the two pamphlets written by Rick Harbo: *A Field Guide to Marine Life of the Protected Waters of the Salish Sea* and *A Field Guide to Marine Life of the Outer Coasts of the Salish Sea and Beyond*. These two works take a similar approach to quick identification of intertidal life, but are definitely designed to be thrown into any pocket. In order to accommodate a drastic reduction in size, a more targetted region and fewer species are included. Both guides focus on the Salish Sea, the region roughly encompassing the marine region east of Vancouver Island, west of the lower BC mainland, and stretching down into Puget Sound in Washington State. The two guides roughly divide this region into an inner protected region and an outer coastal region. Understandably, there is some overlap in species. Like Sept's book, species accounts are presented taxonomically. Sticking with the condensed format however, fewer biological details are given for each species. Despite these restrictions, each species still gets a full colour photograph and over 75 species are included in each pamphlet.

All three of these publications can be valuable tools for those venturing out on the Pacific Coast. The cost is very reasonable and durable construction ensures that they should survive more than a few trips to the shore. The only difference is the relative size and biological depth that each provides. Certainly, any one of these works would be a valuable purchase for those, like me, who want to go to the shore and be able to identify most of the fascinating lifeforms that they will encounter.

JOEL F. GIBSON

Curator, Entomology, Royal BC Museum,
Victoria, BC

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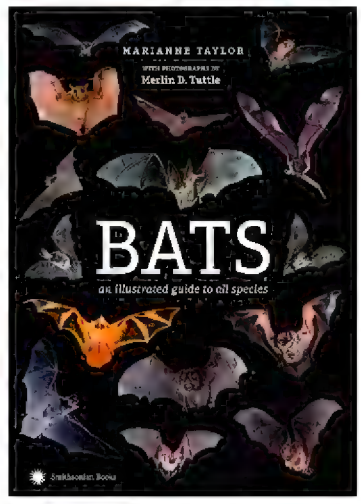
Bats: An Illustrated Guide to All Species

By Marianne Taylor. Photography by Merlin D. Tuttle. 2018. Smithsonian Books. 400 pages, 39.95 CAD, Cloth.



Part lavishly illustrated desktop field guide, part coffee table book, this stunning hardcover is a triumph of production quality. From the cover through to the index, this book has the look and feel of a text three times its price. Not only do the colour saturation and satisfying weight of paper stock do justice to the incredible images, the book is intuitively organized and rendered in exquisite detail.

Starting with a well written and accessible 50-page introduction section that offers an overview of everything from evolution, diversity, and biology to behaviour and bat-human relationships, the bulk of this book is in the species descriptions, organized by suborder, family, and species. As advertised, it covers the 1384 currently recognized bat species of the world, following the 2018 bat taxonomic review by Simmons and Cirranello (2019). Each species is represented by at least a portrait, as well as its distribution (details and map), physical description, and a few interesting facts. The length, weight, and IUCN status of each species is also provided.

Although lacking a species key and not designed as a true field guide, the level of detail in the family and genus descriptions is more reminiscent of a textbook than a popular science entry. While Taylor largely avoids jargon throughout, the long-form descriptions interspersed between the species accounts do have a noticeably different tone. Casual readers will likely enjoy the more accessible Introduction section and enjoy the book as a curio for its beautiful photography and interesting facts. There is certainly enough here for those with a keener interest, but they will have to seek out further reading on their own as the book provides no citations for the information presented.

The highlight of this book is certainly the photography, much of which captures night-time scenes. The bat portraits are all the more impressive for the way they capture the likeness of their subject. It should be said that this is a good resource to win over the bat-fearing folk among us—aside from a handful of very unusual looking adaptations, bats are by and large endearing creatures and Tuttle captures them with remarkable skill. Taking charismatic photos that show a bat's natural expression (i.e., avoiding squinting eyes from a nocturnal animal exposed to flash) is not an easy task, but the night-time photography, and especially the action shots, in this book are simply unparalleled.

If the author's and photographer's objectives were to create a spectacular photo inventory of bat species, prefaced by interesting front matter and interspersed with highly detailed family and genus descriptions, they have met and exceeded their goals. The care, time, and effort put into this book are obvious. Dr. Tuttle has studied and photographed bats for 60 years, and his photo collection combined with Taylor's clear writing are what make this book possible. The result is a gorgeous, informative catalogue of species which absolutely deserves a place on your bookshelf.

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HEATHER A. CRAY
Halifax, NS, Canada

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Mammal Tracks and Sign: A Guide to North American Species. Second Edition

By Mark Elbroch with contributions by Casey McFarland. 2019. Globe Pequot / Stackpole Books. 680 pages, 49.95 USD, Paper, 47.50 USD, E-book.

The first edition of this magnificent guide was published 16 years ago. As Mark Elbroch explains in his Preface, the second edition is less personal—though it retains personal stories as introductions to the chapters—and more rigorous in terms of added depth of detail. It contains less about the "tools of the trade" (p. v), because basic information is now readily available through increasing online resources. Some adjustments in species inclusion were made, primarily removing any south of Mexico. Surprisingly, the second edition is shorter than the first (by just over 100 pages), a result of being tightened up, with white space at a premium and photos sometimes smaller. In sum, if you have the first, you wouldn't be amiss to acquire this edition as well.

Senior author Elbroch and contributor Casey McFarland have extensive experience tracking animals. They are both certified Senior Trackers under the CyberTracker Conservation program, started in South Africa by biologist David Lieberman, who was inspired to develop CyberTracker freeware following his experiences with Kalahari Desert bushmen, whose lives depend on their ability. Elbroch is involved as well with Pathera, a big cat conservation organization, as Director of its Puma Program. His 10 books have been well received, the first edition of this guide being one of several of his books to win a National Outdoor Book Award.

The first chapter provides a brief and succinct introduction to this prodigiously illustrated and comprehensive guide. "Tracking is … field ecology", the authors note, that "grounds us in the natural history of a place" and provides "a natural bridge to science" (p. 2). Extensive, detailed knowledge is required to track successfully, but, they caution, one must always keep in mind the dangers of drawing conclusions without it.

A hundred pages are required in Chapter 2 to cover "Mammal Tracks and Track Patterns". Feet make tracks, Elbroch reminds us, and the first section of this chapter follows its opening story with descriptions and sketches of the morphology of mammalian feet. But the tracks these feet produce have their own, obverse morphology, and eight questions are presented that relate the tracks to the feet that created them. Track morphology can be affected by many things, including substrate (sand, soil, snow), sexual dimorphism (helpful in sexing individual animals), and the animal's age. The many types of locomotion (gaits, hops, gallops, etc.) are covered in detail, with diagrams and illustrations of each, before the discussion turns to interpretation of tracks. This is an imaginative, speculative process that requires the tracker "to build a working hypothesis and test it" against later observations of the animal's behaviour as evidenced in its tracks: "we either toss out our original hypothesis and create a new one, or continue to refine and support it" (p. 45). This lengthy chapter concludes with a "Reference guide to mammal tracks", 46 pages of plates of life-size tracks, each example—as throughout the book's illustrations—keyed to the long, final section of species accounts.

Seven subsequent chapters follow this format of text plus grouped illustrations, the latter having their own colour-coded page edges making these sections easy to find. In the course of their movements and other activities, mammals leave behind plenty of sign which offers rich and diverse clues to who they are and what they were doing. Thus, the emphasis shifts from tracks to sign, beginning with a discussion in Chapter 3 of the "Runs, Paths, and Eskers" created by the movements of animals. (Also known as trail castings, eskers are the backfilling materials deposited in snow tunnels created by the smallest mammals [p. 113].) Animals eat and then excrete, the subject of the fourth chapter. Scat is the primary topic, because urine, being hard to find, remains understudied generally. It can have its uses, however—Elbroch has an amusing account of tracking a Bobcat by sniffing the urine it had sprayed on "scent posts", moving and sniffing from post to likely post to figure out its movements (p. 445). The short Chapter 5, "Nests, Lodges, and Other Constructions", describes the often difficult to identify shelters animals "construct … from materials they collect and manipulate" (p. 178); the shelters are organized under the likely places to find them. The next three chapters cover sign left on the ground, beginning with discussion in Chapter 6 of "diverse signs" (p. 192) created in the course of bedding down, rooting around for food, taking a dust bath, or making below-ground dens. Signs are also left "on Fungi, Herbaceous Plants, and Cacti" (Chapter 7) and "on Trees and Shrubs" (Chapter 8). While these are generally the result of feeding (Chapter 7), they can also be produced by climbing, stripping off bark, browsing on twigs, and taking advantage of tree cav-

ities (Chapter 8). Fourteen pages of colour plates are required to detail the "Sign on mast crops" alone. The penultimate chapter is not for the squeamish—it deals with "Interpreting Prey Remains" in gruesome, full-coloured detail. A suite of forensic skills is required when dealing with remains, one of the most difficult areas of tracking to decipher. This chapter is full of questions to consider and authoritative references to consult; techniques and data to aid with interpretation are offered, including, for example, a chart of the spread between upper and lower incisors of various mammals.

The topics of the preceding chapters are the basis for the rich data presented on each species described in Chapter 10, "Species Accounts". The *Revised Checklist of North American Mammals North of Mexico, 2014* (Bradley *et al.* 2014) provides the taxonomic orders for 261 pages of individual species accounts. This is the most technical part, with data presented in small print, including measurements of front and hind tracks, trail strides of various kinds, and other measurable elements, all organized along the lines of the chapter headings. Sketches and photographs abound. The species themselves are named but not described—the evidence they leave behind is the constant topic. The trails data sections are frequently followed by notes describing that species' movements under varying conditions.

By now, the reader can be forgiven for concluding—with good reason—that using tracks and sign is a more demanding and complex means of mammal identification than looking at the mammal itself. To summarize the authors, it's a matter of detective work, close observation, detailed and intricate knowledge, plus a healthy dose of humility—the capacity to accept and admit one's inevitable mistakes. Becoming a good tracker takes time, experience, and patience plus the helpful analyses presented in this excellent guide. It's on the heavy side for packing in the field, but it's well organized and indexed, so useful whether in the field or in the study. Anyone interested in the topic will learn from this book. It opens up a new universe for exploring the natural world for those coming fresh to the topic and no doubt contains much for those with experience. As the authors note early on, it's not only easy to get it wrong, but costly in terms of natural history. This guide will help.

A final note: Stackpole Books is to be congratulated on its publication of another fine field guide in its tracks and sign series. This one on mammals joins guides on birds (co-authored by Elbroch; Elbroch *et al.* 2001), reptiles and amphibians (Tkaczyk 2015), and insects (Eiseman *et al.* 2010), all similar in form and topics covered.

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BARRY COTTAM

Ottawa, ON, and Corraville, PEI

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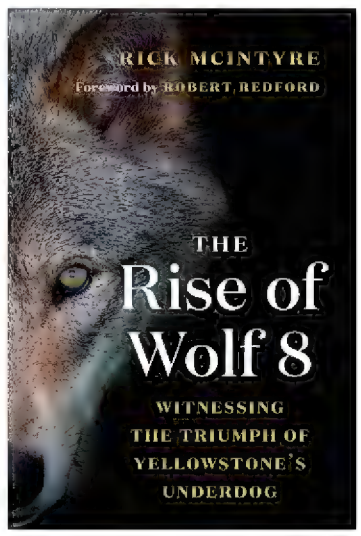
The Rise of Wolf 8: Witnessing the Triumph of Yellowstone's Underdog

By Rick McIntyre. 2019. Greystone Books. 304 pages, 34.95 CAN, 26.95 USD, Cloth.



Rick McIntyre has spent over 40 years observing wolves in national parks, including Denali, Glacier, and Yellowstone. *The Rise of Wolf 8* is part one of a planned trilogy of his nearly 25 years of observing Yellowstone wolves. What is significant about this book is that the author is the source for this story. For the past 20 plus years, many people have written about McIntyre, his colleagues, and the Yellowstone wolves through interviews and television documentaries. But now we get to hear from the man himself. And the book doesn't disappoint. The profiles of individual wolves found in this book are unparalleled for a carnivore, especially here in North America where most carnivores are elusive, usually being active away from people, in forested areas, and at night. As Doug Smith says in the Afterword, "Rick has become a global ambassador for wolves … what you have just read is one of the most personal and in-depth insights into wolves ever produced" (p. 267). I agree! The only resource that I can compare it to is Jane Goodall's *The Chimpanzees of Gombe* (1986, Belknap Press), which describes the lives of individual chimpanzees in unprecedented detail. The same is true of McIntyre's observations of wolves; his knowledge of individuals provides a remarkable real-life narrative of wild wolves.

Hoping just to see a wolf during the first summer (1995) that they were reintroduced to the park (pp. 19–20), McIntyre observed a pack for hours on his first day there and went on to observe more wild wolves than any other human in history, as documented in the Afterword of this book (pp. 265–267). He has had over 100 000 wolf sightings as of January 2019 (p. 267), aided by radio-telemetry, spotting scopes, and a cadre of wildlife watchers and professionals assisting him. He once went out an indefatigable 6175 consecutive straight days into the park, saw wolves 892 days in a row, and has compiled a journal of over 12 000 pages (pp. 265–266)! Over the years, he has been a critical resource for thousands of people in observing wild wolves which is important because observing carnivores is a major economic driver in many regions (Way and Bruskotter 2012), with people specifically visiting regions where carnivores are protected to have "peak life experiences" (McIntyre 2016). Rick was an important source for my own book, *My Yellowstone Experience* (2013, White Cottage Publishing), so it is probably not surprising that I was revelling in the opportunity to review this book.

After a brief background describing his childhood and earlier park service jobs, mostly up in Alaska at Denali and in Texas at Big Bend, the book starts in 1994 in Yellowstone where McIntyre was the country's first "Wolf Interpreter" for the park service. There he primed about 25 000 park visitors that summer about the return of wolves to Yellowstone (p. 10). The next few chapters discuss the reintroduction project—some of the human actors involved as well as the early wolves, brought from Alberta (near Jasper National Park) to Yellowstone. We learn that Wolf 8 of the Crystal Creek pack was the smallest male brought to Yellowstone, a Coyote-like 72-pound (32.6-kg), grey coloured male (p. 15) called "the little guy" (p. 29). He was frequently picked on by his three larger brothers while they were held in an acclimation pen to reduce their homing instincts (Chapter 3).

The most important story in the book, and arguably one of the most important events in the annals of Yellowstone wolf reintroduction, was Wolf 8 leaving his birth pack as a 1.5-year-old to join up with Wolf 9 and her eight pups of the Rose Creek pack (Chapter 6). Wolf 9's mate #10 had been illegally killed outside the park in April 1995, so 9 and her pups were brought back to the park soon after and kept in an acclimation pen until October. Just before the planned release of the wolves, 8 showed up and greeted and fed two of the pups who had escaped the pen during a summer storm. Park employees immediately released the rest of the wolves and the ten wolves formed a cohesive pack led by step-father wolf 8 who protected his new pack (e.g., pp. 48–50) and regularly had to go out and hunt prey animals much bigger and stronger than he was (pp. 248–249). Wolf 8 proved his worth by eventually fathering 54 pups over his life (p. 232).

McIntyre moved full-time to Yellowstone in 1999 to immerse himself in the wolves' world (p. 182). Thus, *The Rise of Wolf 8* is highly personalized as it is about individual wolves, similar to *Wild Wolves We Have Known* which details the lives of famous wolves studied around the globe (Way 2016). But two things stand out in McIntyre's book: 1) it is about individual wolves studied in one area; and 2) studying individuals is becoming more and more frequent, despite the stereotype that biologists shouldn't ascribe names and emotions to their study subjects. Thus, this book normalizes the importance of individual—not just populations of—animals. We clearly see that wolves

have individual personalities, are social, and love to play—all characteristics of higher-order animals like humans. We learn that play is vitally important for bonding within packs as well as preparing them for real world circumstances; McIntyre provides a list and vivid descriptions of these games throughout the book (e.g., pp. 210, 227, 228, 242).

The culmination of the book was "The Battle of Specimen Ridge" (Chapter 27) between Wolf 8's Rose Creek pack and his step-son 21's Druid Peak pack. McIntyre's Shakespearean description of the encounter is absolutely riveting. He noted that 8's determination to battle the much larger 21, who was undefeated in battle situations with other wolves (p. 263), was the bravest thing he had ever seen, "a fight that 21 could not lose and one 8 could not win" (p. 257). Wolves 8 and 21 were never known to have killed other wolves and there are repeated accounts throughout the book of them letting rivals go (p. 262). This is exceptional because they were both alpha wolves for years and wolves killing each other is the most common cause of death where people don't kill them (p. 179). Wolf 8 was battle-worn and had many debilitating injuries (pp. 247–248). Yet he soldiered on, fueled solely by willpower (p. 249), until June 2000 when he died from either an Elk's kick to his head or drowning soon afterward (p. 260). Dying in combat, McIntyre noted, was an honourable ending to his life—it was a good death (p. 261).

At the beginning of the book McIntyre noted (p. xix) that all the elements of a great tale are present, including warfare, betrayal, murder, bravery, compassion, empathy, and loyalty, yet a literary genius such as Dickens or Shakespeare was not available to write this story. I disagree. I believe that McIntyre himself was the perfect person to write this wonderful account. He combines his extraordinary level of observation of wolves with great storytelling (p. 265).

For fans of Yellowstone or wolves, this book is priceless, with a historic feel to it that is palpable. I wholeheartedly recommend it and believe that readers interested in nature, carnivores, and individual animals will be fascinated to learn about the wolves described here and in forthcoming volumes of McIntyre's planned trilogy. McIntyre (2016) has described viewing Yellowstone wolves as a "peak life experience". Reading this book and gaining the insights into Yellowstone wolves that McIntyre provided in unparalleled detail was a 'peak reading experience' for me! I eagerly await the next edition of the Yellowstone wolf saga.

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JONATHAN (JON) WAY
Eastern Coyote/Coywolf Research,
Osterville, MA, USA

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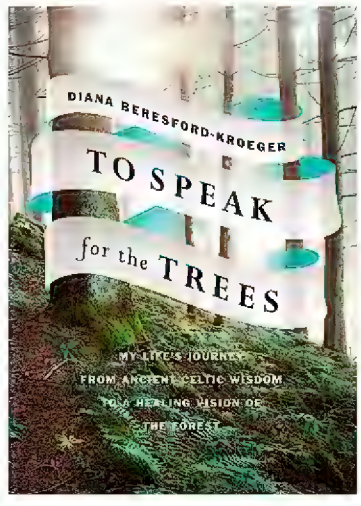
OTHER

To Speak for the Trees: My Life's Journey from Ancient Celtic Wisdom to a Healing Vision of the Forest

By Diana Beresford-Kroeger. 2019. Random House Canada. 289 pages, 32.00 CAD, Paper.



Diana Beresford-Kroeger is a name that has become increasingly well-known in recent years. Awareness and acceptance of her work has been a long time coming. Variously described as a classical botanist, medical biochemist, and protector of forests, Fellow of The Royal Canadian Geographical Society, and—in a delightful poke at the conservative elements that resist her message—"an enemy of the people" (https://www.insideottawavalley.com/news-story/5463236-diana-beresford-kroeger-is-now-an-enemy-of-the-public/; accessed 10 September 2019), she is at once grounded in local activities and at home in world-wide travels through various media. She has published some 300 scientific papers, but the public has come to know her through her previous half-dozen books (or more, depending how you count the editions), published over the past 20 years, and more recently the film *Call of the Forest*, now streaming on the Internet

(https://www.youtube.com/watch?v=T0asL2LfPFk). Not bad for someone who echews email and social media as taking too much time from her real work (D. Beresford-Kroeger pers. comm. 13 August 2019)!

Trees have been at the centre of her explorations and writings, and she combines in her study and advocacy two broad and apparently disparate streams, the scientific fields of botany and biochemistry and the esoteric realm of ancient Celtic beliefs and practices regarding nature. Now, in her latest book, she relates the personal story behind this double expertise. *To Speak for the Trees* doesn't begin with the *Ancient Celtic Wisdom* noted in the subtitle; rather, it begins with an account of the difficult life of a misplaced soul whose journey began in trauma and tragedy. These hard beginnings contain the roots of the dual streams noted above. Her father's family came from a long lineage of wealth and status, her mother's from an even longer lineage dating back to the Celtic/Druidic world, based in Lisheens Valley, County Cork, Ireland. The former was the source of the trauma; tragedy—the deaths of her parents within months of each other when Diana was 12—propelled her initially into the world of science as shared with an uncle who took her in. The serendipitous discovery of her capacious intellect, revealed through her photographic memory, lifted her into deeper studies, at university but also while under the care of her Celtic relations with whom she spent her summers. That aging community decided she would be the ideal exponent of their traditional knowledge and proceeded to teach her everything they knew. Thus, her increasingly happier world came to be divided, productively, between science and indigenous Celtic lore.

The first six chapters cover all this and more. In Chapter 7, "But Where are the Trees?", the book moves on to its central substance, her love of, and life-long relationship with, trees and her increasing awareness of their absolute essentiality to the survival of other forms of life on earth. The title question for this chapter relates to her realization that the ancient forests of Ireland had largely disappeared. Thus began her quest to understand what happened and why, a quest that ultimately took her around the world, inspired a great deal of original research, and led to the insight—and she is marvellous at gaining insights—that if the trees disappear, we disappear, the dependency is that tight (p. 114). This fundamental principle is at the core of a life of activism and the development of her "global bioplan" (p. 159) for addressing climate change, the gravest single problem faced by humanity today. Her research results coalesced into this practical plan, one she lives, with her husband, Christian Kroeger, on 160 acres (64.75 hectares) of land they call Carriglaith, near Merrickville, south of Ottawa. Chapter 11, "My Own Work in My Own Way", recounts the story of developing this land into what amounts to a gene bank of trees hardy enough to live in northern climes as temperatures rise.

The paragraph above compresses the second half of Part One of the book. As her work progressed, she came to understand that she "could serve as a bridge between these two worlds, the ancient and the scientific" (p. 98). Her account is bravely personal, for she is frank about how the suppression she experienced growing up and into early adulthood continued through misogynistic workplaces and the reluctance of the scientific community to accept the esoteric and spiritual elements her research revealed. She took strength from these experiences, however, coming to realize that her background was essential to her ability to think for herself, to refuse to suffer fools gladly, to stand firm for her growing beliefs in the power of trees, and to bring this into form through her actions, from the land she and Christian manage to promoting her hard-won knowledge through the books and documentary noted above, to advising many groups and governments. Examples of her efforts are described in the final chapters of Part One, which concludes with her "Philanthropy of the Mind", the combination of her "scientific knowledge and … energy" (p. 76) that drives her and, she hopes, will inspire all of us to act.

In Part Two, she returns to her roots to provide us with "one more gift …: my annotation of the Ogham script, … the first alphabet of Europe, in which every letter is named for a tree or an important companion plant of trees" (p. 189). There are 20 letters, each receiving an account that mingles poetically scientific knowledge of the trees with ancient Celtic lore, starting with A/Ailm, Pine, and ending with Z/Straif, Blackthorn. Old uses, now largely lost, medicinal properties, and notes on the alphabet itself are melded into each of these brief notes.

This is a courageous, highly readable book, yielding insights of value and leaving us—field naturalists, researchers, nature lovers—with much to think about. The discoveries Diane Beresford-Kroeger has made are at last entering the mainstream, as a source of knowledge and inspiration for the increasing numbers of people concerned with the physical and future state of the planet.

BARRY COTTAM

Ottawa, ON, and Corraville, PEI

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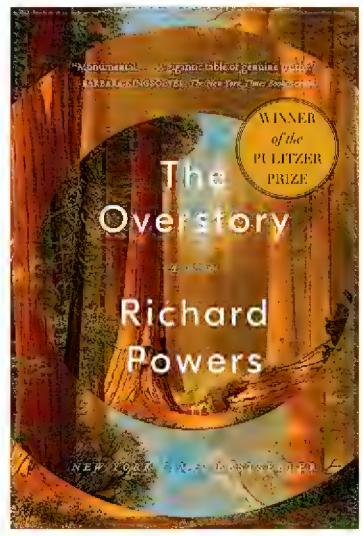
The Overstory: A Novel

By Richard Powers. 2018. W.W. Norton. 512 pages, 27.95 USD, Paper.



Readers of *The Canadian Field-Naturalist* might reasonably wonder why a novel would be reviewed in its pages. A precedent of sorts was set several issues ago with our first review—at least on my watch as Book Review Editor—of a book of poetry, Alice Major's *Welcome to the Anthropocene* (Citron 2017). But a novel? This isn't just any novel, however—it's a brilliant evocation of the life and times of trees as understood, misunderstood, used and abused, by the one species on Earth that supposes itself to be dominant—*Homo sapiens*, you and I and all the other 8 billion or so humans alive today. The entire book, from its title on out, is structured along the lines of and about trees. The title is a play on words, referring at a literal level to the overarching canopy of trees in a forest, the collective crowns of the tallest trees, while signalling the author's ambition to tell as fully as possible the richly complex story of trees as sentient beings and their interactions with humans.

This Powers does brilliantly, in language that flows with an unusually high degree of authenticity. The novel has four sections: Roots, Trunk, Crown, and Seeds. The first is the only one with subtitled chapters, nine of them, named for the characters introduced in each. I was a bit puzzled at first to read separate stories of such a disparate and seemingly disconnected group of people. Each however had some kind of connection to trees and these early chapters set the stage for Powers' interweaving, in various combinations, the stories of these people in ways that allow him to address his panoramic purpose. We humans take multifaceted approaches toward trees, whether as sources of food and medicines, shelter and fuel, beauty and meditative healing, or the many lines of work they provide, from scientific studies to logging and milling up construction materials. Powers addresses our approaches in ways that reveal our inherent, eternal conflicts arising from our need to preserve ourselves—read lifestyles, economies—and our yearning for connectivity and transcendence. Powers does not resolve these conflicts, however. While reading his book, it's possible to hate and fear the destruction our 'normal' lumbering practices are inflicting on the forests while having sympathy for the people whose jobs are at stake if those practices cease, to engage emotionally with the activists going to increasing lengths to end the destruction while gasping at some of their decisions. The world of science is also revealed as conflicted, especially in the characterization of 'maverick' versus conventional science through the career of Patricia Westerford and her supportive husband Dennis, based on the career pathway of the very real Diane Beresford-Kroeger and her husband Christian Kroeger. Powers has done his homework—he has a reputation as a prodigiously inquisitive researcher—yet weaves his learning into a highly imagined fictional form.

The author's deliberate unwillingness to missionize, to leave the reader pondering these dilemmas, is the strength and power of the book, and reason enough, I think, to review it in these pages. Powers claims his own life was changed as a result of researching and writing this, his twelfth novel. In a recent interview, he declared that "Trees are among the very largest, longest-lived, most successful, and most collaboratively social forms of life on the planet. They live, all at once, in the sky, on the surface, and under the ground … We will learn, as Thoreau says, to resign ourselves to the influence of the earth, or we will disappear" (Brady 2018). The clarity of his personal position notwithstanding, he has managed to resist judgement and condemnation while creating a credible and complex picture of human activities in relation to trees. A number of excellent novels dealing with nature and natural history have come out in recent years, and this is one of the best, shortlisted in 2018 for the Man Booker Prize, winner in 2019 of the Pulitzer Prize in Fiction. Powers sends readers a message worth the time spent to listen to it.

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BARRY COTTAM

Ottawa, ON, and Corraville, PEI

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NEW TITLES

Prepared by Barry Cottam

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BOTANY

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CONSERVATION & ECOLOGY

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The Shock of the Anthropocene: The Earth, History and Us. By Christophe Bonneuil and Jean-Baptiste Fressoz. Translated by David Fernbach. 2017. Verso Books. 320 pages, 25.95 CAD, Paper, 13.99 CAD, E-book.

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A Sparrow's Life's as Sweet as Ours: In Praise of Birds and Seasons. By Carry Akroyd and John McEwen. 2019. Bloomsbury. 128 pages, 12.99 GBP, Cloth.

To the Ends of the Earth: Ireland's Place in Bird Migration. By Anthony McGeehan. 2018. Collins Press, Dublin. 248 pages, 24.99 GBP, Cloth.

ZOOLOGY

†Mammals of Prince Edward Island and Adjacent Marine Waters. By Rosemary Curley, Donald F. McAlpine, Dan McAskill, Kim Riehl, and Pierre-Yves Daoust. 2019. Island Studies Press. 354 pages, 49.95 CAD, Paper.

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OTHER

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Journeys in the Wild: The Secret Life of a Cameraman. By Gavin Thurston. Foreword by Sir David Attenborough. 2019. Orion Books. 441 pages, 16.99 GBP, Cloth or E-book.

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Naturalist: A Graphic Adaptation. By Edward O. Wilson. Adapted by Jim Ottaviani. Illustrations by C.M. Butzer. 2019. Island Press. 208 pages, 31.95 USD, Cloth.

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In Nature's Realm: Early Naturalists Explore Vancouver Island. By Michael Layland. 2019. TouchWood Editions. 288 pages, 40.00 CAD, Cloth.

Neptune's Laboratory: Fantasy, Fear, and Science at Sea. By Antony Adler. 2019. Harvard University Press. 256 pages, 39.95 USD, Cloth.

***North Pole: Nature and Culture**. By Michael Bravo. 2019. Reaktion Books. 256 pages, 24.95 USD, Paper.

Rain Comin' Down: Water, Memory and Identity in a Changed World. By Robert William Sandford. 2019. Rocky Mountain Books (RMB). 360 pages, 22.00 CAD, Paper.

Rainforest: Dispatches from Earth's Most Vital Frontlines. By Tony Juniper. 2019. Island Press. 456 pages, 22.00 USD, Paper, 21.99 USD, E-book.

Turning the Boat for Home: A Life Writing about Nature. By Richard Mabey. 2019. Chatto & Windus. 272 pages, 18.99 GBP, Cloth or E-book.

News and Comment

Upcoming Meetings and Workshops

The Committee on the Status of Endangered Wildlife in Canada

The next Wildlife Species Assessment Meeting of COSEWIC will be held 24–29 November 2019 at the Lord Elgin Hotel, Ottawa, Ontario. See how COSEWIC assigns the status to Canadian wildlife species, the first step in protection and recovery under the federal *Species at Risk Act*. Please contact ec.cosepac-cosewic.ec@canada.ca for the procedure to attend as an observer at least one week before the meeting begins. More information about COSEWIC is available at http://cosewic.ca.

The Society for Integrative & Comparative Biology Annual Meeting

The Society for Integrative & Comparative Biology Annual Meeting to be held 3–7 January 2020 at the JW Marriott Austin, Austin, Texas. Registration is currently open. More information is available at https://burkclients.com/sicb/meetings/2020/site/.

Science, Practice & Art of Restoring Native Ecosystems Conference

The Science, Practice & Art of Restoring Native Ecosystems Conference to be held 17–18 January 2020 at the Kellogg Center, East Lansing, Michigan. Registration is currently open. More information is available at https://conference.stewardshipnetwork.org/.

Midwest Fish & Wildlife Conference

The 80th Midwest Fish & Wildlife Conference to be held 22–29 January 2020 at the BOS Center, Springfield, Illinois. The theme of the conference is: 'Bringing Science Back to the Forefront of Resource Management'. Registration is currently open. More information is available at http://www.midwestfw.org/.

Forests Ontario Annual Conference

The annual conference of Forests Ontario to be held 14 February 2020 at the Nottawasaga Inn, Alliston, Ontario. The theme of the conference is: 'We the Forest'. Registration is currently open. More information is available at https://www.forestsontario.ca/community/annual-conference/.

Society for Range Management's Annual Meeting, Technical Training and Trade Show

The Society for Range Management's 73rd Annual Meeting, Technical Training and Trade Show to be held 16–20 February 2020 at the Sheraton Denver Downtown Hotel, Denver, Colorado. The theme of the conference is: 'Transformation & Translation'. Registration is currently open. More information is available at http://www.srm2020.org/.

Wetland Science Conference

The Wetland Science Conference, a program of the Wisconsin Wetlands Association, to be held 18–20 February 2020 at the Osthoff Resort, Elkhart Lake, Wisconsin. More information is available at https://conference.wisconsinwetlands.org/.

Sedges of the Northern Forest: downloadable digital resource (pdf)

A photographic "atlas" of the sedges of the northern forest was posted online (Version 1.3, 357 pages) in early 2019 by Jerry Jenkins at http://northernforestatlas.org/. The guide contains over 1400 high-resolution digital images of 223 Cyperaceae species occurring in the northeast (including both forest and wetland species). These are composite macro images that are "stacked" to obtain clarity throughout the entire depth of field. The result is a collection of crisp, magnified, almost 3D images that carefully illustrate the distinguishing characters of each species—inflorescences, perigynia, achenes, ligules, and even anthers. The stacked images themselves are a marvel, showing even familiar species anew, with rich detail and subtle beauty.

In itself, this free downloadable resource is not a sedge guide, although it accompanies a Cornell publication that has recently become available (also called *Sedges of the Northern Forest*; 2019, Cornell University Press, see review on pp. 172–173 of this issue of *The Canadian Field-Naturalist*). It is intended to be used together with its accompanying book, or with any of the other excellent field guides and floras recently released (e.g., *Field Guide to Wisconsin Sedges* [Hipp 2008]; *Field Manual of Michigan Flora* [Voss and Reznicek 2012]; *Sedges of Maine* [Arsenault *et al.* 2013]). While it has no keys, schematic diagrams of each genus or section (in the case of *Carex*) highlight main characters. Helpful field marks and key differences with similar species are described and often illustrated. For example, a brilliant comparative page of scaled photos of achenes of the challenging Ovales group is sure to be bookmarked on my copy—think of Peterson's famous watercolour plate of "Confusing Fall Warblers", but for Ovales sedges!

This is a beautiful, portable, searchable resource. As a pdf, it can easily be transferred to a phone or tablet, and taken into the field. When used with regional floras, it will aid both beginners and advanced professionals in the study of this ecologically important, diverse, yet often difficult group.

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HOLLY BICKERTON
Ottawa, ON, Canada

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Club des naturalistes d'Ottawa

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COVER: Rocky Mountainsnail (*Oreohelix strigosa*), one of the 44 terrestrial gastropod taxa found during extensive surveys in the northern Columbia River basin, southcentral British Columbia, 2007–2015. See the article in this issue by Ovaska *et al.* pages 221–234. Photo: K. Ovaska, September 2007.

The Canadian Field-Naturalist

Note

First recorded co-occurrence of *Valvata lewisi* Currier, 1868 and *Valvata lewisi ontariensis* Baker, 1931 (Gastropoda: Valvatidae) from Alberta, Canada, with notes on morphometric and genetic variability

Robert P. Hinchliffe[1,*], Cheryl Tebby[1], and Tyler P. Cobb[1]

[1]Royal Alberta Museum, 9810 – 103a Avenue, Edmonton, Alberta T5J 0G2 Canada
[*]Corresponding author: robert.hinchliffe@gov.ab.ca

Hinchliffe, R.P., C. Tebby, and T.P. Cobb. 2019. First recorded co-occurrence of *Valvata lewisi* Currier, 1868 and *Valvata lewisi ontariensis* Baker, 1931 (Gastropoda: Valvatidae) from Alberta, Canada, with notes on morphometric and genetic variability. Canadian Field-Naturalist 133(3): 189–192. https://doi.org/10.22621/cfn.v133i3.2237

Abstract

Sympatric populations of Loosely Coiled Valve Snail (*Valvata lewisi ontariensis* Baker, 1931) and Fringed Valvata (*Valvata lewisi* Currier, 1868) are documented from Alberta, Canada, for the first time. Both forms have been identified concurrently in aquatic invertebrate survey samples collected from three wetlands in northeastern Alberta by the Alberta Biodiversity Monitoring Institute. Molecular analysis (DNA barcodes) indicates that there is no genetic distinction between *V. lewisi* (*sensu stricto*) and *V. lewisi* var. *ontariensis*. Morphometric measurements show that the degree of open coiling, the character that defines *V. lewisi* var. *ontariensis*, is highly variable in Alberta specimens. Our findings confirm that *V. lewisi* var. *ontariensis* is a phenotypic morph of *V. lewisi*.

Key words: Distribution; range extension; Alberta; Valvatidae; *Valvata*; *Valvata lewisi*; *Valvata lewisi ontariensis*; Alberta Biodiversity Monitoring Institute; ABMI

Loosely Coiled Valve Snail (*Valvata lewisi ontariensis* Baker, 1931; common name from Clarke 1981) is a tiny, enigmatic freshwater gastropod that has rarely been collected since first being described by Frank Collins Baker in 1931. Originally thought to be confined to a few locations in western Ontario, Canada (Baker 1931; Clarke 1973; Figure 1), similar specimens have since been collected as Pleistocene fossils or empty shells in Manitoba, Canada (Clarke 1973), and Minnesota, USA (Bright 1981), with the only other confirmed record of living specimens from the Cottonwood Lake Study area in North Dakota, USA (Hanson *et al.* 2002; Figure 1). Here, we report on the first sympatric collections of *Valvata lewisi* (*sensu stricto*) and *V. lewisi* var. *ontariensis* from Alberta, Canada, and provide notes on morphometric and genetic variability.

In contrast to the distribution of *V. lewisi* var. *ontariensis, Valvata lewisi* Currier, 1868 (Fringed Valvata, according to Turgeon *et al.* 1998) is commonly found across the prairie, parkland, and boreal regions of Canada from Newfoundland to British Columbia, north into the Yukon and Alaska, and south into the northern United States (Clarke 1981; NatureServe 2017; Figure 1). *Valvata lewisi* is a small freshwater snail that seldom exceeds 5 mm in diameter and has a depressed spire, multi-spiral operculum, and bi-pectinate gill (Clarke 1973; Burch 1982). Shell sculpting consists of fine striations on the first one and a half to two whorls, which develop on subsequent whorls into axial lamellae that are usually elevated and blade-like, but may be reduced to coarse collabral threads (Clarke 1973). In comparison, *V. lewisi* var. *ontariensis* exhibits the same characteristics, but, unlike *V. lewisi* (*sens. str.*) where the body whorl directly contacts the preceding whorl, *V. lewisi* var. *ontariensis* exhibits open coiling in which the last one to one and a half whorls are separated (Baker 1931; Figure 2).

Valvata lewisi var. *ontariensis* has been detected at five wetlands in Alberta, Canada, through the ongoing activities of the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI collects biological information on a wide range of terrestrial and aquatic organisms across the province using

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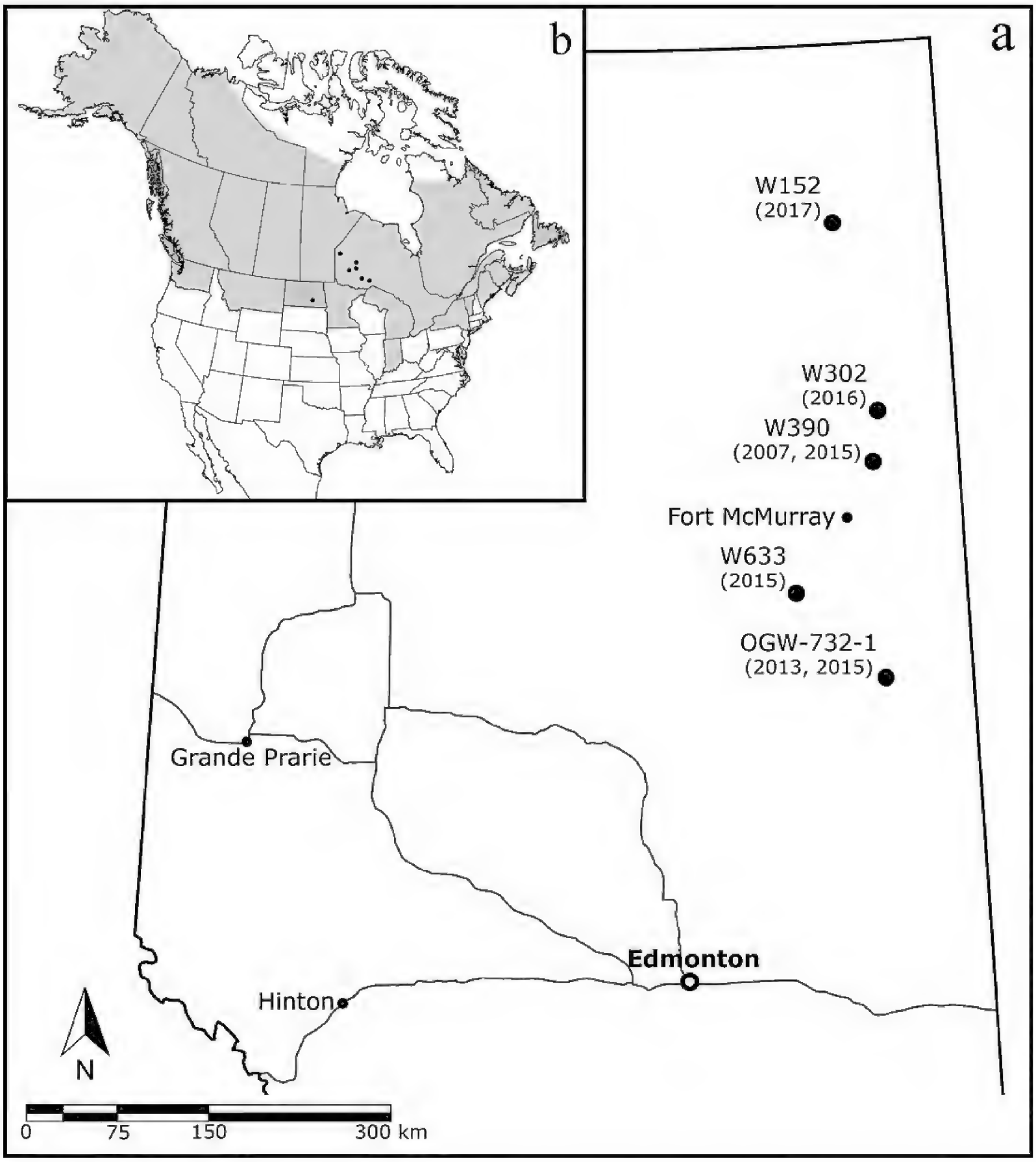

FIGURE 1. a. Alberta Biodiversity Monitoring Institute wetland site locations where specimens of *Valvata lewisi* var. *ontariensis* have been documented in Alberta (large solid circles, collection years in parentheses). Inset map b. shows known range of *Valvata lewisi* (*sensu stricto*) in North America (shaded area) with historical collection records of *V. lewisi* var. *ontariensis* (solid circles).

standardized, publicly available methods (e.g., ABMI 2015, 2018). During routine taxonomic analysis of aquatic invertebrate samples collected by the ABMI in 2007, we detected 12 *V. lewisi* var. *ontariensis* specimens in samples obtained from a permanent wetland in the northeastern part of the province (ABMI site W390; 57.26899°N, 110.72157°W; Figure 1). Following this initial detection, several additional *V. lewisi* var. *ontariensis* specimens were subsequently recovered from ABMI samples collected from the initial detection site and four additional wetlands in the same region—W152 (58.78107°N, 110.86238°W), W302 (57.80382°N, 110.65305°W), W633 (55.97079°N, 112.23922°W), and OGW-732-1 (55.25222°N, 110.91161°W; Figure 1)—for a total collection of 75 specimens. This sampling effort also

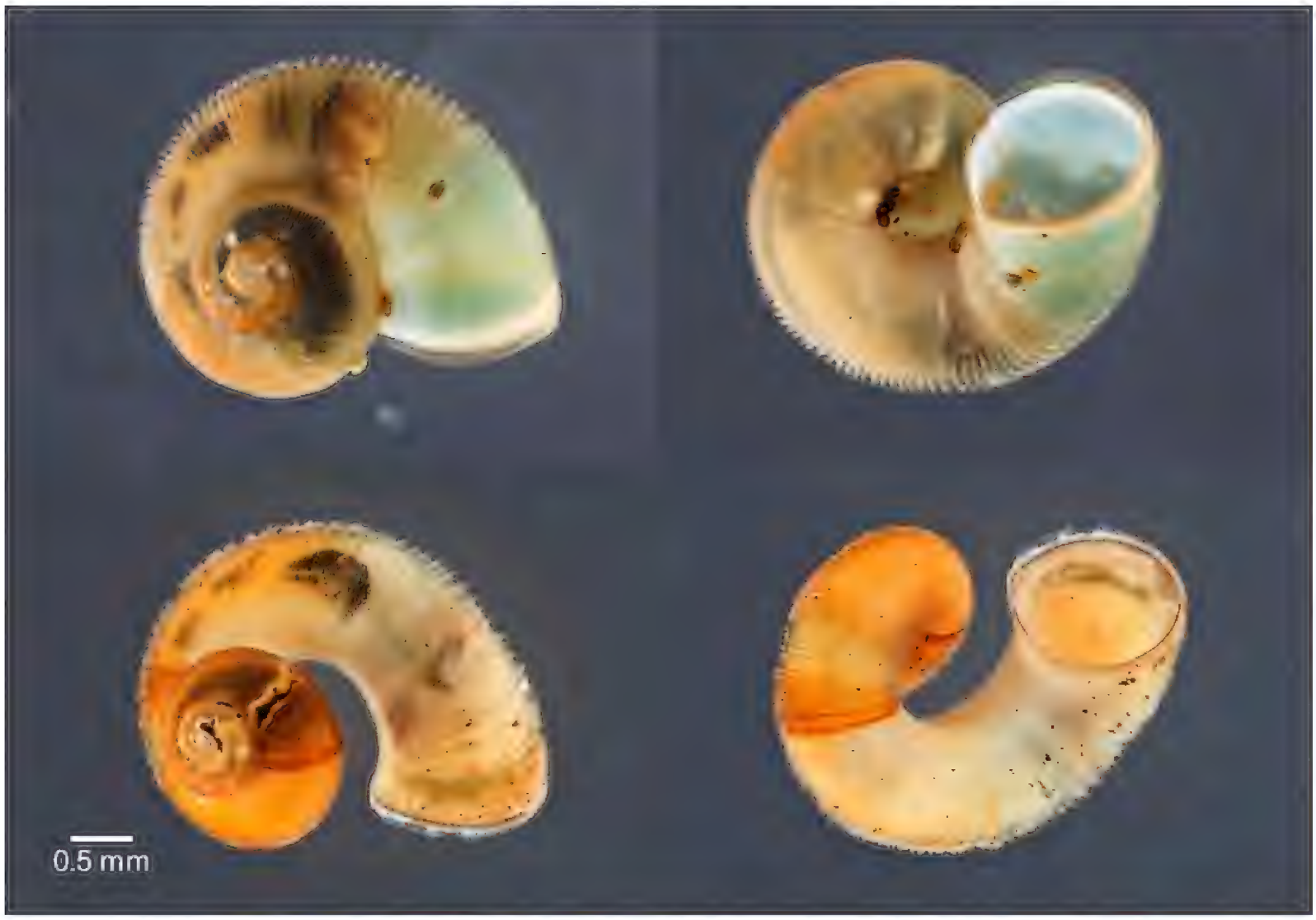

FIGURE 2. Dorsal and ventral views of *Valvata lewisi* (top) and *Valvata lewisi* var. *ontariensis* (bottom). Photos: Robert P. Hinchliffe.

revealed the co-occurrence of *V. lewisi* var. *ontariensis* and *V. lewisi* (*sens. str.*) at sites W390, W633, and OGW-732-1. Voucher specimens have been preserved in 80% ethanol and deposited in the invertebrate zoology collection at the Royal Alberta Museum in Edmonton, Alberta, Canada (ABMI.A.91, ABMI.A.5396, ABMI.A.11900, ABMI.A.15382, ABMI.A.18222, and ABMI.A.30673).

Morphometric analyses of *V. lewisi* var. *ontariensis* revealed considerable variation in the degree of open coiling in Alberta specimens. Measurements showed a clear gradation in the ratio of open-coiled gap to aperture diameter in specimens from both W390 (0.04:1 to 0.22:1, mean 0.10:1, $n = 16$) and OGW-732-1 (0.02:1 to 0.41:1, mean 0.13:1, $n = 18$), a pattern also noted, although not directly measured, by Baker (1931) when examining western Ontario specimens.

Our examination of intra- and inter-specific variability associated with the DNA barcode markers cytochrome c oxidase 1 (CO1) and internal transcribed spacer 2 (ITS2) for *V. lewisi* (*sens. str.*) and *V. lewisi* var. *ontariensis* specimens from sites W390 and OGW-732-1 indicated no genetic distinction between the two morphs. For CO1, the mean interspecific variation (± SD) was 0.17% ± 0.13 with intraspecific genetic distances at 0.16% ± 0.12 for *V. lewisi* (*sens. str.*; $n = 12$) and 0.16% ± 0.14 for *V. lewisi* var. *ontariensis* ($n = 28$). For ITS2, the mean interspecific variation (± SD) was 0.07% ± 0.14 and the intraspecific genetic distance of *V. lewisi* (*sens. str.*; $n = 10$) was 0.03% ± 0.07 and of *V. lewisi* var. *ontariensis* ($n = 23$) was 0.11% ± 0.17. DNA barcoding was conducted by the Canadian Centre for DNA Barcoding in Guelph, Ontario, Canada. Genetic sequences have been submitted to GenBank (CO1: MK721872 to MK721913, ITS2: MK721934 to MK721969).

Our detections of *V. lewisi* var. *ontariensis* constitute the first record of this morph in Alberta, Canada, and the first explicitly documented instances of co-occurrence of *V. lewisi* var. *ontariensis* with *V. lewisi* (*sens. str.*). Clarke (1973: 229) noted that loosely coiled specimens seemed to "occur also (rarely) in some apparently normal populations", but neglected to provide references or observational evidence for this statement. Furthermore, he suggested that the specimens he examined were uniform as all one morph or the other. Other published reports on this species do not make any mention of co-occurrence of the two morphs.

The taxonomic status of *V. lewisi* var. *ontariensis* as a valid subspecies has historically been uncertain (see Baker 1931; Clarke 1973, 1981; Burch 1982).

The working definition of a subspecies is two or more populations of the same species from separate geographic locations with one or more distinguishing characters (Mayr 1942, 1982). The initial Ontario collections identified by Baker (1931) and later expanded on by Clarke (1973) were originally thought to be an isolated and distinct population of the open-coiled morph. Our concurrent collections of *V. lewisi* (*sens. str.*) and *V. lewisi* var. *ontariensis* clearly show that the two morphs can occur in the same water body. This, in addition to the lack of a CO1 or ITS2 barcode gap between the two morphs, supports the conclusion that *V. lewisi ontariensis* is a phenotypic morph of *V. lewisi*.

Despite the broad and common distribution of *V. lewisi* (*sens. str.*), the open-coiled morph has, thus far, been collected in only three isolated regions of North America. Given the widely spaced and seemingly isolated locations where *V. lewisi* var. *ontariensis* has been collected, it is possible that the open-coiled morph is the result of some unknown and possibly localized environmental factor. However, it is also possible that *V. lewisi* var. *ontariensis* is more common than collection records indicate and is simply difficult to detect during routine aquatic invertebrate surveys because of its small size and propensity to burrow into the upper layer of soft substrates (R.P.H. pers. obs.). Targetted sampling in other regions is needed to more fully understand the complete distribution of *V. lewisi* var. *ontariensis*. We recommend that future collections of open-coiled *V. lewisi* specimens be identified and labeled as *V. lewisi* var. *ontariensis* to allow for better tracking of the localities where this morph occurs and perhaps yield additional clues as to the possible source of open coiling.

Author Contributions

Writing – Original draft: R.P.H.; Writing – Review & editing: R.P.H., C.T, and T.P.C.; Visualization: R.P.H.; Conceptualization: R.P.H. and T.P.C.; Investigation: R.P.H. and C.T.; Resources: C.T.; Formal analysis: R.P.H.

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The Canadian Field-Naturalist

Note

Spotless burnsi pattern in Northern Leopard Frog (*Lithobates pipiens*) in Maine

Scott B. Lindemann[1,*], David E. Putnam[2], Malcolm L. Hunter, Jr.[1], and Trevor B. Persons[3]

[1]Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, 5755 Nutting Hall, Room 210, Orono, Maine 04469 USA
[2]University of Maine at Presque Isle, 214 South Hall, Presque Isle, Maine 04769 USA
[3]206 Bigelow Hill Road, Norridgewock, Maine 04957 USA
[*]Corresponding author: lindemann.scott@gmail.com

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Abstract

We document the spotless "burnsi" morph in Northern Leopard Frog (*Lithobates pipiens*) in Maine.

Key words: Northern Leopard Frog; *Lithobates pipiens*; amphibian; pattern variant; Maine

The "burnsi" mutation in Northern Leopard Frog (*Lithobates pipiens*) results in loss of the frog's characteristic spots from the back, and sometimes also from the dorsal surface of the legs (McKinnell *et al.* 2005). Herpetologists have studied this mutation since the early 20th century, and Moore (1942) demonstrated that the burnsi mutation allele is dominant over the wild-type allele. More recently, this mutation has been used to study the effects of genetic bottlenecks in this species of conservation concern (McKinnell *et al.* 2005). This mutation is reported most frequently in central Minnesota and the surrounding area, where it occurs in 4.0–7.1% of *L. pipiens*, although it has also been documented rarely outside this region (Merrell 1965; Brown and Funk 1977; McKinnell *et al.* 2005; Rogers and Peacock 2012).

On 3 June 2018, S.B.L. and D.E.P. discovered a burnsi-type *L. pipiens* (Figure 1) along the bank of the north branch of Presque Isle Stream (46.641949°N, 68.177440°W) on Scopan Maine Public Reserved Land, T11 R4 WELS township, Aroostook County, Maine, USA. The frog was sitting in grass along a stream channel lined with Speckled Alder (*Alnus incana* subsp. *rugosa* (Du Roi) R.T. Clausen), which was further surrounded by scrub-shrub wetland and mixed coniferous–deciduous forest. The frog was identified as *L. pipiens* by the gold colouration of the dorsolateral fold, lack of colouration on the groin, white venter, and green dorsum. Four wild-type conspecifics were also found at the same site (Figure 1).

Burnsi-type *L. pipiens* have been collected from only one other locality in Maine, as determined from a review of the Maine Amphibian and Reptile Atlas Project (MARAP 2019) database, which is maintained by the Maine Department of Inland Fisheries and Wildlife. MARAP contains specimen records from most major North American herpetology collections, as well as most smaller regional ones. In addition, MARAP includes observations from the citizen science iNaturalist Web site (www.inaturalist.org). Four specimens at the American Museum of Natural History (AMNH 51343–6) were collected in 1940 in Woodland (i.e., Baileyville, located 175 km south-southeast of the June 2018 collection), Washington County; these were briefly noted by Merrell (1965), but he did not provide catalog numbers or specific locality data. In addition, the Museum of Comparative Zoology houses a series of specimens (MCZ 25541–50) collected on the same date and from the same locality as the AMNH specimens, and the MCZ catalog ledger notes: "Of the 36,000 frogs collected in three seasons, about 4% were unspotted, but in other respects wholly typical like the true *pipiens* occurring at the spot, intergrades between them were present also".

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FIGURE 1. Burnsi-type (a) and wild-type (b) Northern Leopard Frogs (*Lithobates pipiens*) from Presque Isle Stream, Aroostook County, Maine, USA. Photos: Scott B. Lindemann.

Some of the specimens at both AMNH and MCZ retain spotting on the hind limbs similar to ours, while others are completely unspotted. Assuming the MCZ catalog ledger note is accurate, the burnsi mutation was apparently, at least at this location in Maine, as common as reported in central Minnesota and surrounding areas. We have not surveyed the Woodland area for Leopard Frogs, and the MCZ catalog ledger also states that "The pond has since been destroyed by peat cutting". Aside from this series of specimens, the Presque Isle Stream individual is the only example of unspotted *L. pipiens* we are aware of from Maine.

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Note

Axanthism in Green Frogs (*Lithobates clamitans*) and an American Bullfrog (*Lithobates catesbeianus*) in Maine

Scott B. Lindemann[1,*], Aidan M. O'Brien[1], Trevor B. Persons[2], and Phillip G. DeMaynadier[3]

[1]Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, 5755 Nutting Hall, Room 210, Orono, Maine 04469 USA
[2]206 Bigelow Hill Road, Norridgewock, Maine 04957 USA
[3]Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, Maine 04401 USA
*Corresponding author: lindemann.scott@gmail.com

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Abstract

We document eight cases of axanthism in Green Frogs (*Lithobates clamitans*) and one case in an American Bullfrog (*Lithobates catesbeianus*) in Maine. Although this mutation has been previously reported for both species, this is the first confirmed documentation of "blue" *L. clamitans* and *L. catesbeianus* from Maine.

Key words: Green Frog; *Lithobates clamitans*; American Bullfrog; *Lithobates catesbeianus*; amphibian; blue colour variant; axanthism; Maine

Although "blue" frogs have been documented since 1885 (Haller 1885; also cited in Berns and Uhler 1966), Jablonski *et al.* (2014) note that axanthism is one of the least known colour aberrations in anurans. Axanthism results from the absence or alteration of xanthophores, the dermal chromatophores responsible for red and yellow pigmentation (Berns and Narayen 1970). Normally, these xanthophores contain pteridines and carotinoids, which cause the underlying blue iridophores to appear green; in their absence, the skin appears blue (Berns and Narayan 1970). Berns and Uhler (1966) noted that blue Green Frogs (*Lithobates clamitans*) and Northern Leopard Frogs (*Lithobates pipiens*) have been recorded from northeastern United States (mentioning Maine specifically) and southeastern Canada, although they did not state which species were found in which state or province. Of 111 blue frogs they examined from throughout eastern North America, 100 were *L. clamitans*, 10 were *L. pipiens*, and one was an American Bullfrog (*Lithobates catesbeianus*; from Kentucky). Dodd (2013) cited reports of blue *L. clamitans* from Massachusetts, Delaware, and Virginia, but not Maine. Desroches and Rodrigue (2004) illustrated a blue *L. clamitans*; although not stated, it was presumably from Quebec. Dodd (2013) included a photograph of a blue *L. catesbeianus*, but did not give its locality, and Gilhen and Russell (2015) reported three blue *L. catesbeianus* from Nova Scotia.

On 9 June 2018, S.B.L., James A. Elliott, and A.M.O. found an axanthic adult male *L. clamitans* (Figure 1) in a small pool with emergent vegetation in an ~10-year-old clearcut in coniferous forest, T5 R11 WELS township, Piscataquis County, Maine, USA (46.116659°N, 69.211416°W). Roughly 20 additional wild-type conspecifics were also found at the same location. Axanthic *L. clamitans* (all adults) have also been photo-documented from the following localities in Maine: Washington, Knox County, 11 August 2010; Wiscasset, Lincoln County, 4 October 2013; Buxton, York County, mid-June 2017; Phillips, Franklin County, 16 August 2017; Raymond, Cumberland County, 16 September 2017; and Bethel, Oxford County, 15 July 2018 (MARAP 2019). Although these were coloured similarly to the individual in Figure 1 (i.e., metallic greenish-blue over the entire dorsum), an additional one, from Hurd's Pond, Swanville, Waldo County (44.476658°N,

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FIGURE 1. Axanthic adult male Green Frog (*Lithobates clamitans*) from T5 R11 WELS township, Piscataquis County, Maine, USA, 9 June 2018. Photo: Scott B. Lindemann.

69.032297°W) was piebald blue-green (Figure 2).

In contrast to *L. clamitans*, only a single axanthic *L. catesbeianus* has been documented from Maine (MARAP 2019). A subadult (or small adult) female (Figure 3) was photographed at Headquarters Pond, Cobscook Bay State Park, Edmunds Township, Washington County (44.849505°N, 67.167045°W) by Owen and Raymond Brown on 19 June 2011.

To our knowledge, these represent the first confirmed records of axanthic *L. clamitans* and *L. catesbeianus* from Maine. We do not know the true incidence of axanthic frogs in Maine. The MARAP database contains 773 records of *L. clamitans* and 445 of *L. catesbeianus*, but these records are not the result of systematic surveys, and the resulting ratios of axanthic frogs to normally pigmented ones (1:97 for *L. clamitans* and 1:445 for *L. catesbeianus*) are undoubtedly overestimates, as axanthic individuals are much more likely to be reported. Based on data from midwestern supply houses, Berns and Uhler (1966) estimated that out of a sample of roughly two million frogs, axanthics (mostly *L. clamitans*) occurred at a frequency of about 1:29 000, although in some local areas the rate was as high as 1:318 (22 of 7000). Our data support Berns and Uhler's (1966) finding that axanthism appears to be most common in *L. clamitans*. Like albinism, axanthism is presumably a heritable trait (Bechtel 1995). Whether there is a potential selective advantage or disadvantage to axanthism is unknown, but its rarity suggests that it is likely neutral or even potentially disadvantageous. Further documentation of axanthic specimens, such as those reported here, is conducive to an improved understanding of taxonomic and geographic patterns in this interesting colour aberration.

FIGURE 2. Piebald axanthic adult male Green Frog (*Lithobates clamitans*) from Swanville, Waldo County, Maine, USA, 27 June 2016. Photo: Trevor B. Persons.

FIGURE 3. Axanthic American Bullfrog (*Lithobates catesbeianus*) from Cobscook Bay State Park, Edmunds Township, Washington County, Maine, USA, 19 June 2011. Photo: Raymond Brown.

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Harpalejeunea molleri subsp. *integra* (R.M. Schuster) Damsholt new to Atlantic Canada

Sean R. Haughian[1,2,*] and Thomas H. Neily[3]

[1]Botany & Mycology Section, Department of Natural Sciences, New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[2]Biology Department, Saint Mary's University, 923 Robie Street, Halifax, Nova Scotia B3H 3C3 Canada
[3]Mersey Tobeatic Research Institute, 9 Mount Merritt Road, P.O. Box 215, Kempt, Queens County, Nova Scotia B0T 1B0 Canada
*Corresponding author: sean.haughian@smu.ca

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Abstract

Harpalejeunea molleri subsp. *integra* (R.M. Schuster) Damsholt is reported for the first time in Atlantic Canada. It was found on the base of a large Eastern White Cedar (*Thuja occidentalis*) in a swamp in Nova Scotia. The specimen was examined using light microscopy, diagnosed using standard keys, and compared with reference specimens, including two European collections from the New Brunswick Museum, two North American collections annotated by R.M. Schuster, and the only material that may have been previously collected in Canada, by T. Drummond. We speculate on the original location of Drummond's collection, and the implications of this finding for conservation.

Key words: Liverwort; Nova Scotia; hepatic; Lejeuneaceae

Introduction

Harpalejeunea molleri (Stephani) Grolle (Lejeuneaceae) is a rare leafy liverwort (Note: liverworts typically do not have common names) with a disjunct global distribution, primarily around the North Atlantic, with European and North American populations recognized as subspecies. In Europe, *Harpalejeunea molleri* subsp. *molleri* has been collected on the west coast of Norway and in the United Kingdom, Ireland, and Spain (GBIF 2018), as well as Finland, Italy, Madeira, the Azores, the Canary Islands, and Corsica (Hodgetts 2015). The North American subspecies, *Harpalejeunea molleri* subsp. *integra* (R.M. Schuster) Damsholt, is known primarily from the Appalachian Mountain Range and Atlantic Coastal Plain in the southeastern United States, where it has been collected in Alabama, Georgia, Kentucky, and North and South Carolina (Schuster 1980; Consortium of North American Bryophyte Herbaria 2017), as well as Florida, Mississippi, Tennessee, and Virginia (Breil 1970). A single specimen is thought to have been collected from Canada by Thomas Drummond in the early 19th century, but the collection location is ambiguous, and no other specimens are known to have been collected in Canada since then. Two recent collections are also reported from Brazil, without subspecific designation (GBIF 2018).

The correct name for *H. molleri* and its infraspecific taxa has historically been a source of confusion. Schuster (1980) used the name *Harpalejeunea ovata* (Dickson) Schiffner, and, consequently, much of the material in North American herbaria has been accessioned under that name. However, Grolle (1989) demonstrated that this name is a synonym of *Douinia ovata* (Dickson) H. Buch (Scapaniaceae) and that *H. molleri* is the correct name for the taxon, as recognized recently by European authorities (Paton 1999; Damsholt and Pagh 2002). Nevertheless, the former taxonomic confusion continues to impede accurate delineation of the species' distribution because many herbarium records have not been revised to reflect current taxonomy.

In North America, *H. molleri* subsp. *integra* has been found in old growth swamps or riparian areas with relatively open forest canopies, most commonly as an epiphyte on the base of hardwood trees (Breil 1970; Schuster 1980) and in crevices on sedimentary rock (Consortium of North American Bryophyte Herbaria 2017). It is often in mixed species colonies (Breil 1970), and common liverwort associates in herbarium records include *Frullania asagray-*

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ana Montagneagne, *Lejeunea lamacerina* (Stephani) Schiffner, *Lejeunea ruthii* (A. Evans) R.M. Schuster, *Lejeunea ulicina* (Taylor) Gottsche, Lindenberg & Nees, and *Radula obconica* Sullivant (Consortium of North American Bryophyte Herbaria 2017).

Methods

The collection site was a mixedwood swamp near Hectanooga, Digby County, Nova Scotia (~44.082°N, 66.056°W). Geologically, this part of Digby County is underlain by the Church Point Formation, which is composed primarily of grey to green, fine- to medium-grained metasiltstone and metasandstone, with rare shale deposits (White and Horne 2012). Soils are stony in places and poorly drained, being a mix of peat, sandy loam, and loam-till derived from slate (Hilchey *et al.* 1962). The habitat is a rich swamp forest, dominated by Eastern White Cedar (*Thuja occidentalis* L.), Red Maple (*Acer rubrum* L.), Balsam Fir (*Abies balsamea* (L.) Miller), and Yellow Birch (*Betula alleghaniensis* Britton). Hummock and hollow microtopography characterizes the ground layer, with hummocks dominated by sedges (*Carex* spp.) and Cinnamon Fern (*Osmundastrum cinnamomeum* (L.) C. Presl) and hollows dominated by *Sphagnum* spp. and standing water. The shrub layer is patchy, with Common Winterberry (*Ilex verticillata* (L.) A. Gray) and Grey Alder (*Alnus incana* (L.) Moench).

Collections of *H. molleri* subsp. *integra* were made opportunistically during searches for *Frullania selwyniana* Pearson, also rare in the province. Approximately 40 mature cedar trees were visually inspected during this search; eight were found to host visible mixed-species colonies of leafy liverworts. A mixed-species collection was made from each of the eight host trees and later examined using stereomicroscopy. Liverworts were identified using standard taxonomic keys (Schuster 1980; Paton 1999).

Two of these collections were found to contain *H. molleri* subsp. *integra*. The larger of the two collections was then compared with reference material from three sources: (1) two exsiccatae from the herbarium at the New Brunswick Museum (NBM), (2) two recent collections from the United States that were annotated by liverwort authority R.M. Schuster at the Field Museum (F), and (3) the original (supposedly) Canadian collection by T. Drummond, held by the New York Botanical Garden. Neither S.R.H. nor T.H.N. has since had the opportunity to return to this location to assess the population size or health of the colony.

In this paper, we provide a brief description of the morphology of the specimen that was deposited at the NBM as evidence for our subspecific designation. We also highlight noteworthy aspects of the historical collections for the sake of comparison.

Results

Harpalejeunea molleri subsp. *integra* was collected from two cedar trees in the Hectanooga Cedar Swamp. One of these collections was accessioned at the NBM, while the other is held in the private herbarium of T.H.N. Common species in these colonies included *Frullania asagrayana* Montagne, *Frullania oakesiana* Austin, *Ptilidium pulcherrimum* (Weber) Vainio, and *Radula complanata* (L.) Dumortier, while rarer species included *F. selwyniana*, *Lejeunea cavifolia* (Ehrhart) Lindberg, and *Lejeunea ulicina* (Taylor) Gottsche, Lindenberg & Nees. Both of the (mixed-species) colonies, in which *H. molleri* subsp. *integra* was detected, were ~40 cm^2 on the bases of large Eastern White Cedars (~25 cm diameter at breast height). *Harpalejeunea molleri* subsp. *integra* occupied only a small fraction (<10%) of the colonies and the subsequent collected material, but was distinct from the other species present, being obviously greener than *F. selwyniana*, larger than *L. ulicina*, and with more acutely angled leaves than *L. cavifolia*.

Shoot and colony architecture of *H. molleri* subsp. *integra* in the collected material corresponded to a previously published description (Schuster 1980). The collective, multi-species colony structure for our sample was that of a loose "smooth mat", although each individual species exhibited a thread-like growth form (*sensu* Bates 1998). Shoots of *H. molleri* subsp. *integra* were 0.4–0.6 mm wide (transverse axis, including leaves) and displayed a dichotomous irregular lateral branching pattern. Stem postical cortical cells were 13–15 µm wide on mature shoots. Leaves were two-ranked, spreading, and complicate-bilobed with alternate insertions along the stem (Figure 1). Antical leaf lobes were comma shaped and longer than broad (1.1–1.2 length to width ratio); proximal margins overlapped the stem above the transverse insertion (Figure 2), and distal margins were acute tipped, typically tapering to a single cell, or occasionally two cells and often curved toward the substrate (Figure 3). The smaller, postical lobe (lobule) attached to the stem along the entire length of its proximal margin and folded under the larger, antical lobes, forming a rounded keel along the anterior leaf margin (Figure 3); the angle between the distal edge of the keel and the free antical lobe ranged from 90° to 120°, and the joint was often strongly indented (Figure 2). The distal tips of most lobules bore a slightly elongated, tooth-like cell, located proximal to the distal margin of the keel; this cell projected away from the stem and was ~1.5–2 times the length of a median lobule cell (Figure 3). Immediately proximal

FIGURE 1. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

FIGURE 2. Antical view of *Harpalejeunea molleri* subsp. *integra* shoot, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

to this tooth-like cell, some lobules also had a clavate, hyaline papilla (not shown). Underleaves were 0.12–0.16 mm across, shallowly bilobed, and widely divergent; each lobe was four cells wide at the base and rounded at the apex (Figure 4). The specimen had no obvious reproductive structures.

The two collections from North America (F) were consistent with Schuster's (1980) descriptions of *H. molleri* subsp. *integra*. They exhibited stem postical cortical cells 13–19 µm in width, bilobed underleaves with four cells at the base of each lobe, and strongly indented leaf margins where the distal terminus of the lobule's keel attached to the antical leaf lobe.

The two collections from Spain and Portugal (NBM) had characters consistent with Schuster's (1980) and Paton's (1999) descriptions of *H. molleri* subsp. *molleri*. Compared with the USA material, they had consistently wider postical cortical cells of 19–23 µm, more weakly indented joints (forming angles of ~90–135°) between the lobule and leaf lobe, and slightly more variable underleaf lobe widths (4–7 cells).

Drummond's collection was somewhat transitional between the European and the North American collections examined; the leaf lobe–lobule joints were

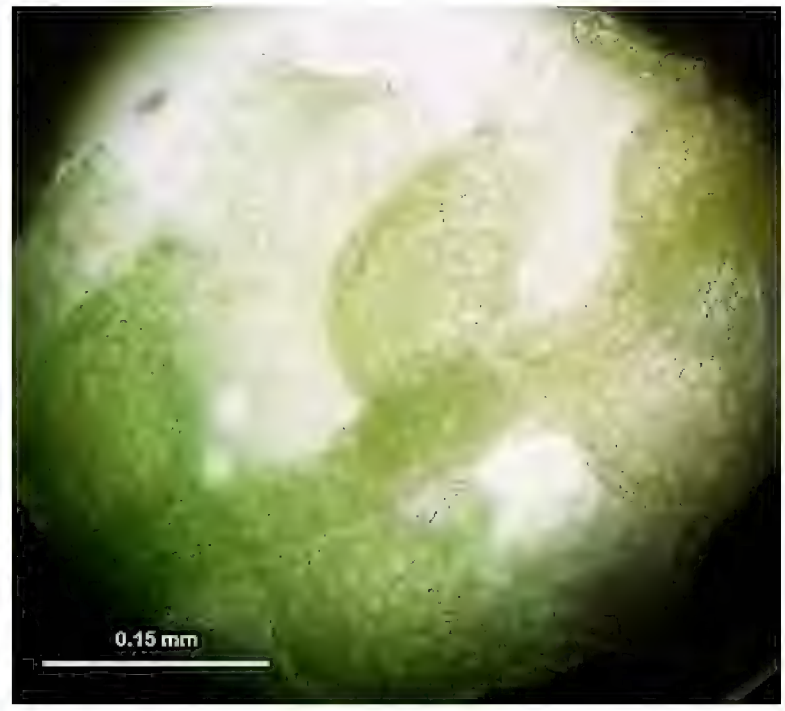

FIGURE 3. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot, showing lobules, underleaves, and antical lobe tips, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

FIGURE 4. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot, showing underleaves and cortical stem cells, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

strongly indented on mature stems, and the underleaf lobes were mostly 4 (-6) cells across. However, the postical cortical cells of the stem were wider (19–24 µm) than is typical for *H. molleri* subsp. *integra*. Associated taxa in this packet included *Diplophyllum albicans* (L.) Dumortier and *Frullania tamarisci* (L.) Dumortier. The only writing on the packet was the former Latin name of the species ("*Lejeunea ovata*") and the vague place-name, "British North America".

Discussion

This is the first report of *H. molleri* subsp. *integra* in Atlantic Canada, and the first reliable report of the species in Canada. The apparent disjunction of this occurrence from other known localities in North America suggests that the population is a relic of a previously more contiguous North American distribution, that it is a recent colonist from the southeast, or that the species is present between the new sites and the ones further south but unrecorded. We think the latter is unlikely given the search effort for mosses and liverworts in much of the northeastern United States and the uniqueness of the Nova Scotia habitat.

Alternatively, *H. molleri* subsp. *integra* may be a dispersal-limited disjunct of Nova Scotia's Atlantic Coastal Plain flora. This species is only rarely fertile, even in locations where it is more common and abundant (Breil 1970; Schuster 1980). Consequently, reproductive propagules are unlikely to have colonized any new habitats in recent years. Moreover, other species that are associated with this type of habitat (both vascular plants and epiphytes) are known to be associated with the Atlantic Coastal Plain, for which southwestern Nova Scotia forms a natural northern disjunction (Sweeny and Ogilvie 1993). Regardless, the combination of potential dispersal limitation with habitat and substrate associations, makes *H. molleri* subsp. *integra* an exceptional rarity, even among flora of the Atlantic Coastal Plain.

The first record in Canada?

Although our find was exceptional, it may not be the first detection of this species in Canada; a single collection of *H. molleri* was supposedly made by T. Drummond in the early 19th century and is held by the New York Botanical Garden. The location originally listed in the digital record of the specimen was "British Columbia" (Consortium of North American Bryophyte Herbaria 2018), but the writing on the packet says "British North America", a vague term, which, at the time the collection was made (ca. 1830), could have referred to all of the British territories north of the United States (Nicholson 2006) or primarily those west of Upper Canada, which was both the official name and a more commonly used descriptor for material collected by Drummond from what is now southern Ontario (Consortium of North American Bryophyte Herbaria 2018). If the specimen was indeed from Ontario, Drummond would probably have made this collection at the beginning of his expedition in 1825 (the only time he visited Ontario), which began in the Niagara area, and proceeded toward Lake Superior, and then on to the Rocky Mountains via the Saskatchewan River route (Bird 1967). It is possible that he considered much of northwestern Ontario to be outside of Upper Canada *sensu stricto*.

However, we have reasons to doubt that this collection was from Canada. First, the collection was part of William Mitten's herbarium, which was both extensive and somewhat poorly organized and annotated (Thiers 1983), casting a general doubt on the accuracy of packet labels.

Second, the associated taxa in Drummond's collection (*D. albicans* and *F. tamarisci*) are, in Canada, primarily known from either the British Columbia coast or the Atlantic provinces, where Drummond did not collect; other supposed early records of *D. albicans* (Macoun 1902) probably represent *Diplophyllum taxifolium* (Wahlenberg) Dumortier (Ley and Crowe 1999).

Third, most other Drummond bryophyte collections from the Ontario region list a specific area (e.g., "Lake Superior" or "Niagara Falls"; Consortium of North American Bryophyte Herbaria 2018), many of which would have been considered part of Upper Canada, rather than "British North America".

Fourth, while lands around Lake Superior are known to harbour some rare taxa associated with cedar swamps (e.g., COSEWIC 2019), neither Drummond's own records nor those of others who have studied Drummond's work (Bird 1967) suggest that he sampled extensively in cedar swamps of Ontario.

Fifth, the Drummond *H. molleri* collection could be from another location entirely: the specimen is somewhat morphologically ambiguous, with stem cortical cells suggestive of the European subspecies, perhaps from the United Kingdom (UK), and other morphological aspects suggestive of *H. molleri* subsp. *integra*, perhaps from the southeastern USA.

Drummond is known to have sampled bryophytes extensively in the UK before his work in North America, as exemplified in his two-volume *Musci Scotici* (Geiser 1937), and to have travelled widely throughout the southeastern USA in the 1830s, amassing thousands of specimens, including exsiccatae entitled *Musci Americani* and *Musci Louisiana*, which were posthumously released by Hooker and Wilson (Hooker 1840; Short 1841; Geiser 1937). The associated taxa in his *H. molleri* collection do not provide definitive guidance on alternative localities: in North America, *D. albicans* and *F. tamarisci* are known primarily from the Pacific Northwest or from Atlantic Canada and the Appalachian range of the USA, but have also been recorded in the UK. Nevertheless, we believe the collection was more likely to have been from the southeastern USA. Although hepatics were a minority in all of Drummond's collections and are not fully enumerated in any documents we could locate, Evans (1902) reports that Drummond's "Mosses of the Southern States" contains *Jungermannia serpyllifolia*. Although this name was later consid-

ered a synonym of *L. cavifolia* (Evans 1902), at the time Drummond was collecting, *H. molleri* subsp. *integra* was known as *J. serpyllifolia* subsp. *ovata* (Grolle 1989), and the omission of such a subspecific designation could have been easily overlooked by later handlers of this material. Even if the specimen to which Evans (1902) referred was, indeed, *L. cavifolia*, it suggests that Drummond collected in the right type of habitat to have also recovered *H. molleri*.

Significance and conservation

Although it may be the first Canadian record, our Nova Scotian collection of *H. molleri* subsp. *integra* was not entirely unexpected: the rich swamp forests of southwest Nova Scotia harbour several rare species that are unknown elsewhere (e.g., Neily and Anderson 2010) or are otherwise restricted to the southern Appalachians or Atlantic Coastal Plain of North America (Wisheu and Keddy 1989; Sweeny and Ogilvie 1993). The other liverworts found in the colony with *H. molleri* subsp. *integra* are themselves rare or uncommon in Atlantic Canada, having been reported only a handful of times in Nova Scotia (R. Newell pers. comm. 31 May 2017).

The Hectanooga Cedar Swamp, in which our specimens were collected, has been viewed as rare and exceptional in Nova Scotia for several decades (Ogilvie 1984), but its ecological importance has only been recognized more recently. In addition to an absence of historical disturbance in large parts, with some trees nearly 200 years old (Nova Scotia Department of Environment 2013a), the swamp harbours the largest number of naturally occurring Eastern White Cedar in mainland Nova Scotia (Nova Scotia Nature Trust 2010). The swamp also harbours many rare and at-risk species of lichens (COSEWIC 2009, 2010, 2015, 2016), birds (COSEWIC 2007, 2008), and trees, including Eastern White Cedar (Newell 2005). The Hectanooga Cedar Swamp is, therefore, of considerable value for biodiversity conservation and scientific research.

Historically, much of the Hectanooga Cedar Swamp was privately owned, but large parts are now scheduled to be protected by a provincial Nature Reserve. In 2010, the Nova Scotia Nature Trust purchased 75 ha of this land, and later transferred ownership of it to the provincial government with the protection of a conservation easement. These lands, combined with an adjacent area of Crown land to the north, are proposed as the Hectanooga Cedar Swamp Nature Reserve, including both important swamp forest and some mature mixed hardwood forest to reduce the negative edge influence (Nova Scotia Department of Environment 2013b). On the other hand, logging activities between 2008 and 2012 had already removed a substantial area of adjacent old-growth forest, and several roads run along the edges of the proposed reserve (S.R.H. and T.H.N. pers. obs.). As such, the reserve may yet suffer from negative edge influence, exacerbated by its small size (124 ha), fragmented configuration (divided into three sections), and elongate shape. Such forested wetlands may be declining in Nova Scotia, and these declines may be exacerbated in the future in a warming climate (Newell 2005; Lemieux 2010). We recommend enhancing protections for such unique hotspots of biodiversity by promptly conferring legal protected status upon them wherever possible, by adding additional parcels to make the reserves contiguous, and by increasing reserve sizes to increase protection from adjacent industrial activities.

Vouchers examined

Harpalejeunea molleri subsp. *integra* (R.M. Schust.) Damsh—CANADA, NOVA SCOTIA: Digby Co., Hectanooga Cedar Swamp, 44.082°N, 66.056°W, 17 May 2017, *T. Neily 1629* (NBM BH-2739); *ibidem*: 44.083°N, 66.052°W, 17 May 2017, *T. Neily 1654* (personal collection of T.H.N., Digby Co.); U.S.A., TENNESSEE: Pickett Co., rocky slopes W of Hwy 154 near Scott Co. line, Pickett State Forest, 17 April 1991, *P.G. Davison 1613* (F-C0074242, as *H. ovata* subsp. *integra*); SOUTH CAROLINA: Oconee, gorge of Whitewater River, 0.3–0.4 mi. (0.5–0.6 km) below Lower Falls, *ca.* 3 mi. (4.8 km) above Jocassee, 24 August 1958, *R.M. Schuster 40899a* (F-C0578334, as *H. ovata* subsp. *integra*); BRITISH NORTH AMERICA: *ca.* 1825–1835 (entered as 1906), *T. Drummond s.n.* (NY00265235, as *Lejeunea ovata*).

Harpalejeunea molleri (Steph.) Grolle subsp. *molleri*—SPAIN: 1927, P. Allorge, Exsiccata Bryotheca Iberica No. 11 (NBM BH-00858, as *H. ovata*); PORTUGAL: 1937, P. Allorge, Exsiccata Bryophyta Azorica No. 37 (NBM BH-00519, as *H. ovata*).

Author Contributions

Conceptualization – S.R.H. and T.H.N.; Investigation (specimen discovery & identification) – T.H.N.; Investigation (specimen verifications & comparisons) – S.R.H.; Investigation (nomenclatural & historical research) – S.R.H.; Methods – S.R.H. and T.H.N.; Visualization (photography) – S.R.H.; Writing (original draft preparation) – S.R.H.; Writing (review & editing) – S.R.H. and T.H.N.

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Lichens and allied fungi of Sandbar Lake Provincial Park, Ontario

Hanna R. Dorval[1,*] and Richard Troy McMullin[2]

[1]Lakehead University, Natural Resources Management, 955 Oliver Road, Thunder Bay, Ontario P7B 5E1 Canada
[2]Canadian Museum of Nature, Research and Collections, P.O. Box 3443 Stn. D, Ottawa, Ontario K1P 6P4 Canada
[*]Corresponding author: hdorval@lakeheadu.ca

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Abstract

Sandbar Lake Provincial Park (Sandbar Lake) covers 8053 ha in the boreal forest in northwestern Ontario. Within the park boundary are natural forests representative of those in the region, as well as forests that are heavily disturbed from resource extraction activities, which are prevalent in northwestern Ontario. The lichen biota in this part of the boreal forest is known to be rich and abundant, but lichen diversity is also known to be negatively impacted by disturbances (e.g., timber harvesting, mining, and climate change). Therefore, lichens can be used to monitor the effects of these disturbances, but baseline data are required. Here, we present the results of the first detailed inventory of the lichens and allied fungi of Sandbar Lake. We report 139 species in 69 genera from 16 sites that represent all macrohabitats present in the park. Seven species have a provincial conservation status rank from S1 to S3 (critically imperilled to vulnerable), and one species, *Arthrosporum populorum*, has previously been collected only once in northwestern Ontario. Our results fill biogeographic gaps for many species and allow lichens to be used as biomonitors during further study at Sandbar Lake. We show that Sandbar Lake has important conservation value, and our data provide an opportunity for further study in an area with no previous research on lichens.

Key words: Sandbar Lake Provincial Park; lichens; fungi; boreal forest; Great Lakes–St. Lawrence forest; conservation; biogeography; bioindicators; protected areas

Introduction

Provincial parks in Ontario are designed to maintain and preserve natural and cultural integrity while allowing for recreational and educational opportunities for the public and scientific communities (Ontario 2015). They are regulated under the *Provincial Parks and Conservation Reserves Act* and, since 1954, have been managed by Ontario Parks, a branch of the Ontario Ministry of Natural Resources and Forestry. Between 1920 and 1954, they fell under the Department of Lands and Forests. The first provincial parks in Ontario were created from land that was considered unsuitable for agriculture and settlement. However, now parks are also established to provide opportunities for outdoor recreation and the resulting economic benefits. Parks allow the public and researchers to gain knowledge of the natural heritage of Ontario; they also protect the biodiversity, ecosystems, and provincially significant elements within their boundaries (Ontario 2006). Currently, more than 7 420 816 ha in Ontario have been incorporated into 335 provincial parks, accounting for 7% of the land area in the province (Ontario 2017).

Sandbar Lake Provincial Park was established in 1970 (Ontario Parks 2012). It was initially classified as a recreation park but was changed to its current classification as a natural environment park in 1986 (Ontario Parks 2012). This designation dictates that the management goals include maintenance of ecosystem representativeness and natural and cultural heritage, while allowing for recreational, educational, and research activities (Ontario Parks 2012). The park area includes Sandbar Lake, sand beaches, and conifer-dominated forests. Since it was established, two additions to the park have doubled its size to over 8000 ha (Ontario Parks 2012). Sandbar Lake Provincial Park is in a region northwest of Lake Superior that is known for rich lichen diversity (Crowe 1994; Ahti and Crowe 1995) and as a hotspot for lichen diversity in North America (Brodo *et al.* 2001). However, the lichens of the Sandbar Lake area have not been documented previously.

The history of lichen collecting in Ontario has been summarized by McMullin and Lewis (2013). Of the 1083 species known from the province (McMullin *et al.* 2015, 2018), at least 455 occur in the region northwest of Lake Superior (Crowe 1994; Ahti and Crowe 1995). Despite the known diversity, the only

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focussed studies within this region of Ontario have been in Slate Islands National Park (C. Wetmore unpubl. data accessed through the Consortium of North American Lichen Herbaria [CNALH]) and Voyageur National Park in Minnesota, USA (Wetmore 1981).

The aim of our study was to document the lichens and allied fungi in Sandbar Lake Provincial Park. Our objectives were to examine all major ecosystems in the park, create a checklist of lichens and allied fungi traditionally treated with lichens, compare our results with those from two other provincial parks in Ontario, and provide provincial conservation status ranks for each species. Our results will provide an increased understanding of the biodiversity in the park and a baseline that can be used to detect changes to the lichen community from disturbances, such as climate change, acid rain, or land use changes in or near the park (McMullin *et al.* 2017).

Study Area

Sandbar Lake Provincial Park is located in northwestern Ontario, ~4 km northeast of the town of Ignace and ~250 km northwest of Thunder Bay (Figure 1), along Highway 599. This protected area covers 8053 ha. When the park was established in 1970, its area was 3157 ha. In 1986, 1926 ha were added and, in 2003, Ontario's Living Legacy Land Use Strategy facilitated a second addition of 3720 ha on the north side of the park (Ontario Parks 2012). The latter comprises mainly wetland generated through paludification, where organic matter accumulation, especially *Sphagnum* spp., contributes to increased soil moisture (Lavoie *et al.* 2005; Ontario Parks 2012). This process results in reduced soil temperature, a reduction and overall change in tree and vascular plant cover, and shifts in nutrient availability, microbial activity, and decomposition rates (Lavoie *et al.* 2005).

This wetland is designated a nature reserve zone, which is a classification used to enhance protection of features represented within provincial parks that are considered unique within the region and the province (Ontario Parks 2012). Minimal to no development is permitted within these zones, but research may be permitted. Sandbar Lake Provincial Park contains five nature reserve zones, all of which were examined for lichens during this study. Natural environment zones are areas intended for limited development to generate and maintain low-intensity recreational activities. Development permitted in these zones includes the provision of signage for trail navigation and the maintenance of interpretive facilities. Two natural environment zones covering 6872 ha are present in Sandbar Lake Provincial Park (Ontario Parks 2012). Historical zones were also established in the park to mark and protect culturally and historically significant areas, including those that have historically been occupied by humans and human-made structures (Ontario Parks 2012). Sandbar Lake Provincial Park has four historical zones, each delineated based on human occupation during the Laurel Period (2200–1600 years B.P.) and the Blackduck Period (1200 years B.P. to European contact; Ontario Parks 2012). All nature reserve, natural environment, and historical zones within Sandbar Lake Provincial Park are illustrated in Figure 1.

The park provides opportunities for outdoor recreation, including hiking, canoeing, and seasonal camping at 75 campsites. All campsites and hiking trails are located in the campground area in the southeastern corner of the park adjacent to Highway 599. Use of the campground area and recreational fishing in Sandbar Lake accounts for the vast majority of park use by visitors; the remainder of the park is visited only infrequently.

Sandbar Lake Provincial Park is located within the transition zone between the boreal and Great Lakes–St. Lawrence forests (Ontario Parks 2012). The park comprises mostly conifer-dominated forests; however, mixed-wood forests, wetlands, exposed bedrock outcrops, and outwash plain ecosystem types are also represented (Ontario Parks 2012). Timber harvesting, sporadic fires, and windthrow events, which occurred mainly during the early 20th century, are largely responsible for shaping the vegetation communities currently in the park (Ontario Parks 2012). In recent decades, timber harvesting and mining operations have surrounded the park boundary (Ontario Parks 2012).

Methods

Sampling

Fieldwork was conducted in the fall of 2017. Collections were made throughout the park in all major ecosystems, nature reserves, and natural ecosystem zones over 12 days. Floristic habitat sampling, completed through the intensive study of large areas, was used to evaluate species presence (Newmaster *et al.* 2005). This sampling technique was used at 16 sites, shown with corresponding geographic coordinates and habitat descriptions in Table 1. As many microhabitats as possible were examined in each site: e.g., a variety of tree species, rocks, forest floor. Most sites were visited on only one occasion; however, sites I and II, Campground and Red Pine (*Pinus resinosa* Aiton) forest, were visited more than once. All collections have been deposited at the National Herbarium of Canada (CANL) at the Canadian Museum of Nature Natural Heritage Campus in Gatineau, Quebec.

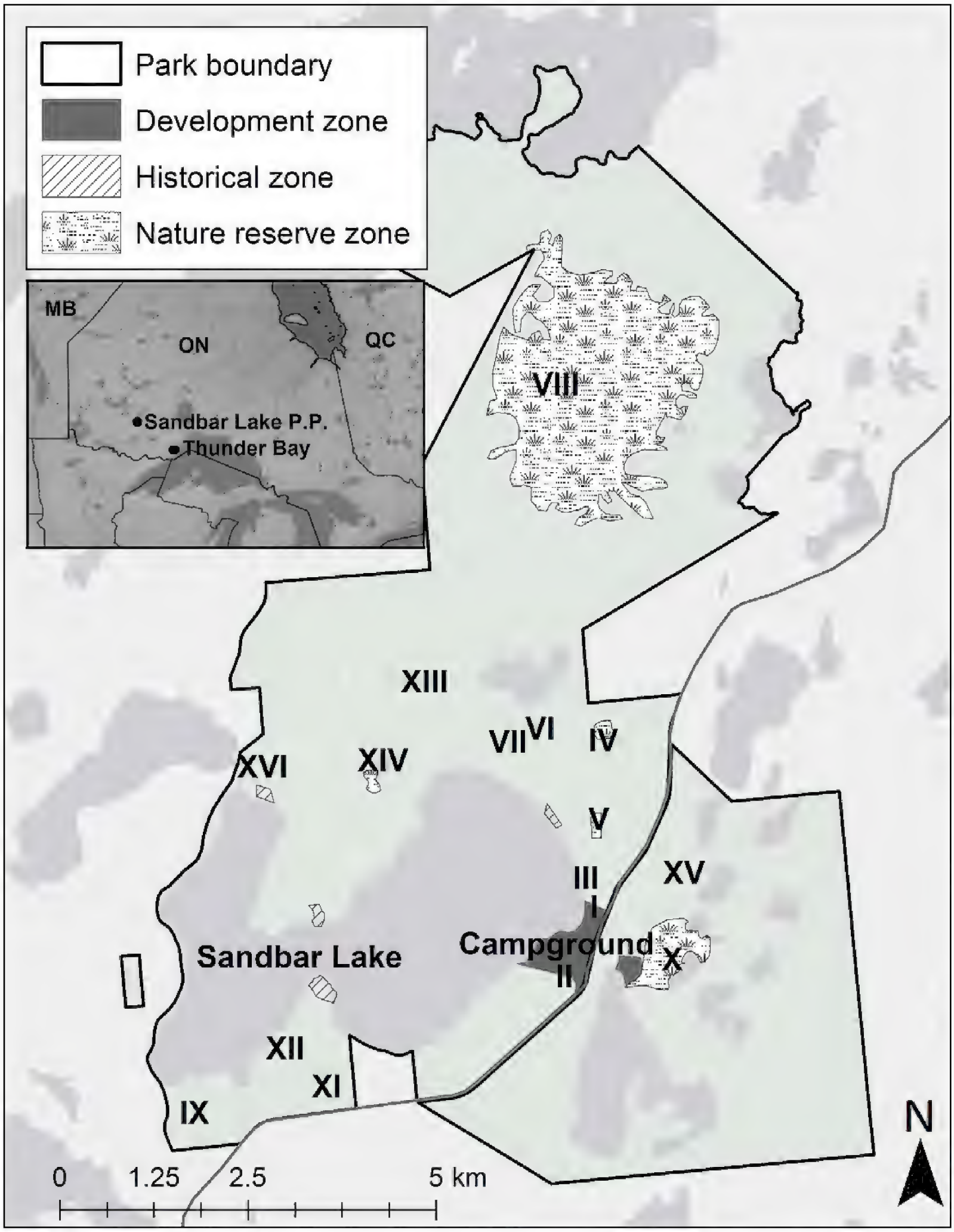

FIGURE 1. Sandbar Lake Provincial Park, showing designated zones and sampling sites.

Identification

All specimens were identified using standard techniques outlined by Brodo *et al.* (2001), including the use of microscopy and chemical spot tests. When necessary, an ultraviolet light chamber was used for additional chemical examination. Thin-layer chromatography was also used in further chemical analysis, following Orange and White (2001) using solvents A, B′, and C.

TABLE 1. Location and description of collection sites.

Site	Location	Latitude (°N)	Longitude (°W)	Habitat description
I	Campground	49.46517	91.55536	Campsites near Sandbar Lake with small, dense patches of forest between them, connected by gravel roadways.
II	Red Pine forest	49.46503	91.55407	Red Pine (*Pinus resinosa*)-dominated forest naturally regenerated after fire, with young Balsam Fir (*Abies balsamea*) in the understorey, adjacent to the campground.
III	Beach forest	49.47220	91.54784	Mixed-wood forest, dominated by Balsam Fir and Balsam Poplar (*Populus balsamifera*), adjacent to sandy beach along the eastern shoreline of Sandbar Lake.
IV	Mixed-wood forest*	49.48950	91.53708	Deciduous-dominated mixed-wood forest with abundant fallen logs and herbaceous groundcover.
V	Jack Pine forest*	49.47955	91.54389	Jack Pine (*Pinus banksiana*)-dominated forest with exposed bedrock, young Black Spruce (*Picea mariana*) understorey, and lichens and mosses forming large thick mats.
VI	Boulder cave	49.48659	91.54849	Caves formed by large boulders leaning against a bedrock cliff, with high humidity and limited light exposure.
VII	Cliff and exposed bedrock	49.48638	91.55068	Exposed bedrock and steep cliffs with mixed-wood forest surrounding the base.
VIII	Treed fen*	49.52254	91.55263	Large, humid, lowland area resulting from paludification, with sporadic Tamarack (*Larix laricina*) and Black Spruce, with sphagnum moss groundcover and a high diversity of wetland vascular plants.
IX	Forest at South Agimak River	49.47526	91.52035	Dense, late-successional, mixed-wood forest with little understorey vegetation, near the South Agimak River and associated wetland.
X	Silhouette trail*	49.46295	91.53601	Mixed-wood forest along Silhouette trail/roadway, with a vegetative community resulting from past resource extraction.
XI	Clearing at Flayers Road	49.45061	91.59702	Treeless clearing along gravel road (Flayers Road) surrounded by Jack Pine, with sandy soil, fallen logs, and exposed bedrock.
XII	Flayers Road fen	49.45850	91.60091	Fen, near Flayers Road, dominated by Tamarack and Black Spruce, with moss covering the ground and some pools of standing water.
XIII	Forest north of Sandbar Lake	49.49306	91.56565	Mixed-wood forest with highly variable structure and age, located between the northeastern shoreline and 1 km north of Sandbar Lake.
XIV	Shoreline of Bog Lake*	49.48997	91.58136	Sedge mat with abundant Tamarack and Black Spruce, few shrubs, and many dead standing trees, surrounding the small lake.
XV	Ontario rangers road	49.47526	91.52035	Road re-colonized by forest dominated by young Balsam Fir, between two lakes to the north and south of the road.
XVI	North Agimak River	49.49087	91.60870	River with exposed and mossy boulders, surrounded by dense mixed-wood forest.

*Indicates the sampling sites in each of the park's five nature reserve zones.

Sorensen–Dice coefficient of similarity

To compare the lichen community at Sandbar Lake Provincial Park with two other locations in Ontario, we used the Sorensen–Dice coefficient of similarity (Dice 1945; Sorensen 1948). This coefficient is calculated as follows:

$$2A/(2A + B + C)$$

where A is the total number of species at Sandbar Lake Provincial Park and another location (e.g., location 2), B is the number of species at Sandbar Lake Provincial Park that are absent from location 2, and C is the number of species at location 2 that are absent from Sandbar Lake Provincial Park (Dice 1945; Sorensen 1948).

The two locations included for comparison, Awenda Provincial Park (McMullin and Lendemer 2016) and Sandbanks Provincial Park (McMullin and Lewis 2014), are study sites with comparable search efforts nearest to Sandbar Lake Provincial Park.

Conservation status

We report the conservation status (S ranks) for each species recorded in the park. The Ontario Na-

tural History Information Centre (NHIC) assigns these non-legal provincial conservation status ranks to species in Ontario, based on guidelines set out by NatureServe (2018). If adequate information is known about the presence of a species in the province, then a rank between 1 and 5 is assigned. An S rank of 1 denotes a species that is considered critically imperilled, 2 means imperilled, 3 is vulnerable, 4 is apparently secure, and 5 is secure. Other ranks include NR meaning not ranked, U meaning unrankable (because of lack of information), and ? meaning the rank is uncertain. Species with a rank of S1 to S3 are provincially tracked. Observations of these species in the province are considered remarkable and are reported to the NHIC. Species with a rank above S3 or are unranked are not provincially tracked and are considered to be fairly common within the province.

Results

We located 139 species in 69 genera at Sandbar Lake Provincial Park (see Annotated species list): 54 (39%) species are crustose, 52 (37%) are foliose, and 33 (24%) are fruticose. For 122 species (88%), green algae are the primary photobiont; for 13 (9%), cyanobacteria are the primary photobiont; and four (3%) are non-lichenized allied fungi.

Sorensen–Dice coefficient of similarity

Sorensen–Dice coefficients of similarity were determined for each of the two other provincial parks and Sandbar Lake Provincial Park. The lichen community at Sandbar Lake Provincial Park is more similar to that of Sandbanks Provincial Park (coefficient value of 0.65) than to that of Awenda Provincial Park (coefficient value of 0.49). The number of species (n = 139) at Sandbar Lake Provincial Park was also more similar to the number found at Sandbanks (n = 122) than Awenda (n = 203). Sandbar Lake Provincial Park is considerably larger than both other provincial parks in this comparison (Table 2).

Conservation status

Of the 139 species discovered at Sandbar Lake Provincial Park, 125 have been assigned conservation status ranks. Seven of these species have a conservation status rank between S1 and S3 (critically imperilled, imperilled, vulnerable) and are provincially tracked. One species is listed as S1S2: *Arthrosporum populorum* A. Massl.; two are S2: *Bacidia laurocerasi* (Delise ex Duby) Zahlbr. and *Ochrolechia pseudopallescens* Brodo; two are S2S3: *Calicium parvum* Tibell and *Chaenothecopsis pusilla* (Ach.) A.F.W. Schmidt; and two are S3: *Cetrelia chicitae* (W.L. Culb.) W.L. Culb. & C.F. Culb. and *Melanelixia glabratula* (Lamy) Sandler & Arup. The non-tracked species include 19 that are S4, seven that are S4?, 27 that are S4S5, 65 that are S5, nine that are not ranked, and five that are unrankable.

Annotated species list

This list is organized alphabetically by genus and species, and taxonomic authorities follow the 23rd version of the North American Lichen Checklist (Esslinger 2018), as does most of the nomenclature. Any differences between this list and Esslinger's reflects the opinion of the authors. Substrate follows species name and taxonomic authorities. Roman numerals indicate the collection site (Table 1). Provincial conservation status rank follows the collection site. Non-lichenized fungi typically treated with lichens are preceded by a dagger (†).

Acarospora fuscata (Schrad.) Arnold—Saxicolous. VII. S5

Amandinea punctata (Hoffm.) Coppins & Scheid.—Corticolous on Balsam Fir (*Abies balsamea* (L.) Miller). I. S5.

Arthonia sp.—Corticolous on a snag. I. SNR.

Arthrosporum populorum A. Massl.—Corticolous on a fallen Trembling Aspen (*Populus tremuloides* Michaux). XIII. S1S2.

Athallia pyracea (Ach.) Arup, Frödén & Søchting—Corticolous on a fallen *P. tremuloides*. XIII. SU.

Bacidia laurocerasi (Delise ex Duby) Zahlbr.—Corticolous. II. S2.

Baeomyces rufus (Huds.) Rebent.—Terricolous on sandy soil. IX. S4S5.

Biatora pycnidiata Printzen & Tønsberg—Corticolous on *A. balsamea* and Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh). IV, XV. SNR.

Biatora vernalis (L.) Fr.—Bryicolous. I. S5.

Bryoria sp.—Corticolous on *P. mariana* and dead *P. mariana*. I, XII, VIII. SNR.

TABLE 2. Sorensen–Dice coefficient of similarity between Sandbar Lake Provincial Park community and two other park communities in Ontario.

Provincial park	Approximate distance from Sandbar Lake Provincial Park	Area (ha)	No. of species	Sorensen–Dice coefficient
Sandbar Lake	0	8053	139	1
Awenda	1018 km southeast	2915	203	0.49
Sandbanks	1254 km southeast	1551	122	0.65

Bryoria furcellata (Fr.) Brodo & D. Hawksw.—Corticolous on *P. mariana* and Jack Pine (*Pinus banksiana* Lambert). I, III, IX, XIII, XIV. S5.

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.—Corticolous on *A. balsamea*. XII. S5.

Bryoria kockiana Velmala, Myllys & Goward—Corticolous on *A. balsamea* and White Spruce (*Picea glauca* (Moench) Voss. I. S4.

Bryoria trichodes subsp. *trichodes* (Michx.) Brodo & D. Hawksw.—Corticolous on *P. mariana*. XII, XIV. S5.

Buellia erubescens Arnold—Corticolous on *A. balsamea* and Paper Birch (*Betula papyrifera* Marshall). I, X, XV. S5.

Calicium parvum Tibell—Corticolous on *P. resinosa*. II. S2S3.

Calicium trabinellum (Ach.) Ach.—Lignicolous on a snag. X. S4S5.

Caloplaca arenaria (Pers.) Müll. Arg.—Saxicolous. VII. S5.

Caloplaca cerina (Ehrh. ex Hedwig) Th. Fr.—Corticolous on a fallen *P. tremuloides*. XIII. S5.

Caloplaca chrysophthalma Degel.—Corticolous on a fallen *P. tremuloides*. I, IV. S4?

Candelariella lutella (Vainio) Räsänen—Corticolous on *Alnus* sp. and on a fallen *P. tremuloides*. I, XIII. SNR.

Candelariella vitellina (Hoffm.) Müll.—Saxicolous. VII. S5.

Carbonicola anthracophila (Nyl.) Bendiksby & Timdal—Lignicolous on burned wood. II. S4?

Cetrelia chicitae (W.L. Culb.) W.L. Culb. & C.F. Culb.—Saxicolous. XVI. S3?

Chaenotheca brunneola (Ach.) Müll. Arg.—Lignicolous on a snag. II. S4.

Chaenotheca chrysocephala Turner ex Ach.) Th. Fr.—Corticolous on *P. mariana*. XIII. S4.

Chaenotheca ferruginea (Turner ex Sm.) Mig.—Corticolous on a charred conifer and *P. resinosa*. II, X. S4.

†*Chaenothecopsis nana* Tibell—Corticolous on *P. mariana*. XIII. SU.

†*Chaenothecopsis pusilla* (Ach.) A.F.W. Schmidt—Corticolous on *P. resinosa*. II. S2S3.

Chrysothrix caesia (Flot.) Körb—Corticolous on *B. papyrifera*. I. S5.

Cladonia botrytes (K.G. Hagen) Willd.—Lignicolous on dead *P. mariana*. VIII. S5.

Cladonia cenotea (Ach.) Schaerer—Lignicolous on rotting wood. II. S5.

Cladonia cornuta (L.) Hoffm.—Terricolous. XI. S4S5.

Cladonia cristatella Tuck.—Lignicolous on a rotted stump; saxicolous; terricolous. I, V. S5.

Cladonia deformis (L.) Hoffm.—Terricolous on thin soil. V. S5.

Cladonia digitata (L.) Hoffm.—Lignicolous on rotting wood and a stump. I, II. S4S5.

Cladonia macilenta var. *macilenta* Hoffm.—Terricolous. XI. S5.

Cladonia merochlorophaea Asah.—Terricolous. I. S4.

Cladonia mitis Sandst.—Saxicolous. V. S5.

Cladonia ochrochlora Flörke—Lignicolous on rotting wood; terricolous. II, XI. S5.

Cladonia parasitica (Hoffm.) Hoffm.—Lignicolous on a log. II. S4.

Cladonia phyllophora Hoffm.—Terricolous. V, XI. S5.

Cladonia pyxidata (L.) Hoffm.—Terricolous. I. S5.

Cladonia rangiferina (L.) F.H. Wigg.—Saxicolous on bedrock. V. S5.

Cladonia stellaris (Opiz) Pouzar & Vězda—Saxicolous on bedrock. V. S5.

Cladonia uncialis (L.) F.H. Wigg.—Terricolous. V. S5.

Cladonia verticillata (Hoffm.) Schaer.—Terricolous. XI. S4S5.

Dermaatocarpon luridum (With.) J.R. Laundon—Saxicolous. XVI. S5.

Dimelaena oreina (Ach.) Norman—Saxicolous. VII. S4.

Evernia mesomorpha Nyl.—Corticolous on *A. balsamea, P. mariana*, and a snag. I, II, III. S5.

Flavoparmelia caperata (L.) Hale—Corticolous on *B. papyrifera*; saxicolous. I, VI. S5.

Flavopunctelia flaventior (Stirt.) Hale—Corticolous on *A. balsamea*. I. S5.

Fuscidea arboricola Coppins & Tønsberg—Corticolous on *A. balsamea*. XV. SU.

Heterodermia speciosa (Wulfen) Trevisan—Bryicolous. I. S4S5.

Hypogymnia incurvoides Rass.—Corticolous on *P. mariana*. XIV. S4.

Hypogymnia physodes (L.) Nyl.—Corticolous on *A. balsamea* and *Picea* sp. I, II, IV, XII, XV. S5.

Hypogymnia tubulosa (Schaer.) Hav.—Corticolous on *A. balsamea* and *Picea* sp. I, XIII. S4?

Imshaugia aleurites (Ach.) S.F. Meyer—Corticolous on a burned snag and dead Eastern White Cedar (*Thuja occidentalis* L.). II, VIII. S5.

Imshaugia placorodia (Ach.) S.F. Meyer—Corticolous on a *P. mariana* log. IX. S4S5.

Julella fallaciosa (Arnold) R.C. Harris—Corticolous on *B. papyrifera*. I. S4?

Lasallia papulosa (Ach.) Llano—Saxicolous. VI. S5.

Lecanora albella var. *rubescens* (Imshaug & Brodo)—Corticolous on *B. papyrifera*. XIII. SNR.

Lecanora allophana (Ach.) Nyl.—Corticolous on a snag. I. S5.

Lecanora allophana f. *sorediata* Vain.—Corticolous on *B. papyrifera* and *P. tremuloides*. I, IX. S5.

Lecanora circumborealis Brodo & Vitik.—Corticolous on Tamarack (*Larix laricina* (Du Roi) K. Koch). VIII. S5.

Lecanora polytropa (Ehrh.) Rabenh.—Saxicolous. VII. S5.

Lecanora pulicaris (Pers.) Ach.—Corticolous on *B. papyrifera*; lignicolous on a *Pinus* sp. cone. I, XIII. S5.

Lecanora symmicta (Ach.) Ach.—Corticolous on *B. papyrifera* and Eastern White Pine (*Pinus strobus* L.). I, X. S5.

Lecanora thysanophora R.C. Harris—Corticolous on *A. balsamea* and a deciduous tree. XIII. S4S5.

Lepra trachythallina (Erichsen) Lendemer & R.C. Harris—Corticolous on *T. occidentalis*. IV. S4.

Lepraria finkii (B. de Lesd.) R.C. Harris—Corticolous on *T. occidentalis*; saxicolous. VI, XVI. S5.

Leptogium cyanescens (Rabenh.) Körb.—Saxicolous on a mossy boulder. I, XVI. S5.

Leptorhaphis epidermidis (Ach.) Th. Fr.—Corticolous on *B. papyrifera*. IX. S4.

Lobaria pulmonaria (L.) Hoffm.—Corticolous on *P. tremuloides*. VII. S4.

Melanelixia glabratula (Lamy) Sandler & Arup—Corticolous on dead *P. strobus*. XIV. S3.

Melanelixia subaurifera (Nyl.) O. Blanco *et al.*—Corticolous on *B. papyrifera*; saxicolous. I, X. S5.

Melanohalea exasperatula (Nyl.) O. Blanco *et al.*—Corticolous on *Alnus* sp. I. S4S5.

Mycobilimbia berengeriana (A. Massal.) Hafellner & V. Wirth—Terricolous. I. S4S5.

Mycoblastus sanguinarius (L.) Norman—Corticolous on *P. mariana*. VIII. S4S5.

Mycocalicium subtile (Pers.) Szatala—Lignicolous on a snag. I, II. S4S5.

Myelochroa glabina (Ach.) Elix & Hale—Corticolous on *B. papyrifera*. I. S4S5.

Nephroma helveticum Ach.—Saxicolous. XVI. S4S5.

Nephroma parile (Ach.) Ach.—Saxicolous on a mossy rock; terricolous. I, XVI. S4S5.

Nephroma resupinatum (L.) Ach.—Corticolous on Mountain Maple (*Acer spicatum* Lamarck); saxicolous on a mossy rock; terricolous. I, XIII. S4.

Ochrolechia arborea (Kreyer) Almb.—Corticolous on *B. papyrifera* and *P. mariana*. I, XIV. S4S5.

Ochrolechia pseudopallescens Brodo—Corticolous on *P. mariana* and dead *P. mariana*. VIII, XIV. S2.

Parmelia squarrosa Hale—Corticolous on *B. papyrifera*. I, XIII. S5.

Parmelia sulcata Taylor—Corticolous on *B. papyrifera* and on a snag. II, X. S5.

Parmeliopsis capitata R.C. Harris ex J.W. Hinds & P.L. Hinds—Corticolous on a conifer, *L. laricina, P. mariana,* and dead *P. strobus*. I, V, VIII, XII. S5.

Parmeliopsis hyperopta (Ach.) Arnold—Corticolous on dead *P. strobus* and a snag. I, V. S5.

Peltigera aphthosa (L). Willd.—Terricolous on mossy soil. II. S5.

Peltigera canina (L.) Willd.—Lignicolous on a rotted log; terricolous on the base of a rock. I, IV. S5.

Peltigera elisabethae Gyeln.—Terricolous on sandy soil. I, III, IV. S5.

Peltigera evansiana Gyeln.—Bryicolous on a mossy boulder. XVI. S4.

Peltigera extenuata (Nyl. ex Vainio) Lojka—Saxicolous and terricolous. I, XIII, XVI. S4?

Peltigera horizontalis (Huds.) Baumg.—Lignicolous on a rotted log; saxicolous; terricolous on the base of a rock. I, IV, XIII. S5.

Peltigera malacea (Ach.) Funck—Terricolous. X. S4S5.

Peltigera neckeri Hepp ex Müll. Arg.—Saxicolous. XI. S5.

Peltigera polydactylon (Neck.) Hoffm.—Saxicolous. I. S5.

Peltigera rufescens (Weiss) Humb.—Terricolous. I. S5.

Pertusaria rubefacta Erichsen—Corticolous on *A. spicatum*. XIII. S4?

Phaeophyscia adiastola (Essl.) Essl.—Saxicolous. I, XVI. S4.

Phaeophyscia hirtella Essl.—Corticolous on *P. tremuloides*. I. S4.

Phaeophyscia pusilloides (Zahlbr.) Essl.—Bryicolous; corticolous on *A. spicatum* and *P. tremuloides*. I, XIII. S5.

Physcia adscendens (Fr.) H.Olivier—Corticolous on *Alnus* sp.; saxicolous. I. S5.

Physcia caesia (Hoffm.) Hampe ex Fürnr.—Saxicolous. I. S4S5.

Physcia millegrana Degel.—Saxicolous. I. S5.

Plasmatia tuckermanii (Oakes) W.L. Culb. & C.F. Culb.—Corticolous. XII. S4S5.

Polysporina simplex (Taylor) Vězda—Saxicolous. VII. S4S5.

Porpidia crustulata (Ach.) Hertel & Knoph—Saxicolous. XIII. S5.

Protoparmelia hypotremella Herk, Spier & V. Wirth—Corticolous on dead *T. occidentalis*. VIII. SNR.

Punctelia rudecta (Ach.) Krog.—Corticolous on *A. balsamea*. I. S5.

Pyxine sorediata (Ach.) Mont.—Saxicolous. VI. S5.

Ramalina dilacerata (Hoffm.) Hoffm.—Corticolous on *Picea* sp. I, XIII. S4.

Ramalina intermedia (Delise ex Nyl.) Nyl.—Saxicolous on a boulder. VII. S5.

Rhizocarpon concentricum (Davies) Beltr.—Saxicolous. VII. SNR.

Rhizocarpon timdalii Ihlen & Fryday—Saxicolous. VII. SNR.

Rinodina freyi H. Magn.—Corticolous on a fallen *P. tremuloides*. XIII. S4S5.

Scoliciosporum chlorococcum (Stenh.) Vězda—Lignicolous on a *Pinus* sp. cone. I. S5.

†*Sphinctrina anglica* Nyl.—Lichenicolous on *P. hypotremella* on *T. occidentalis*. VIII. S4.

†*Stenocybe pullatula* (Ach.) Stein—Corticolous on *Alnus* sp. I. SU.

Stereocaulon dactylophyllum Flörke—Saxicolous. I. S4.

Stereocaulon grande (H.Magn.) H. Magn.—Saxicolous. XVI. S4.

Stereocaulon tomentosum Fr.—Terricolous on mossy soil and on sandy soil. IX, X, XI, XVI. S4S5.

Trapeliopsis granulosa (Hoffm.) Lumbsch—Terricolous on sandy soil. III. S5.

Tuckermanopsis americana (Sprengel) Hale—Corticolous on *B. papyrifera* and on a snag. II, XIII. S5.

Tuckermanopsis sepincola (Ehrh.) Ach.—Corticolous on *L. laricina*. VIII. S5.

Umbilicaria deusta (L.) Baumg.—Saxicolous. VII. S5.

Umbilicaria mammulata (Ach.) Tuck.—Saxicolous. III, VI. S4S5.

Umbilicaria muehlenbergii (Ach.) Tuck.—Saxicolous on a boulder. V, VII. S4S5.

Usnea cavernosa Tuck.—Corticolous on *A. balsamea* and on *P. mariana*. I, III, VIII, XII. S4S5.

Usnea dasopoga (Ach.) Nyl.—Corticolous on a conifer. XII. S5.

Usnea hirta (L.) Weber ex F.H. Wigg.—Corticolous on a snag. II. S5.

Usnea lapponica Vain.—Corticolous on a snag. II. S4?

Usnea subfloridana Stirt.—Corticolous on dead *P. mariana*. VIII. S4S5.

Vulpicida pinastri (Scop.) J.-E. Mattson & M.J. Lai—Corticolous on burned wood and on *P. mariana*; lignicolous on rotting wood. II, V, VIII, XV, XIV. S5.

Xanthomendoza hasseana (Räsänen) Schøting, Kärnefelt & S.Y. Kondr.—Corticolous on *P. tremuloides*. XIII. S5.

Xanthoparmelia plittii (Gyeln.) Hale—Saxicolous. VII. S4S5.

Xanthoparmelia viriduloumbrina (Gyeln.) Lendemer—Saxicolous. VII, XVI. SU.

Discussion

Sandbar Lake Provincial Park hosts a rich diversity of lichens, including many species that are rare in the region and province. For example, *A. populorum*, of which we made a single collection, is only known from nine collections in Ontario, of which only one is in northwestern Ontario (MIN 879779). This species is almost exclusively collected from the bark of Trembling Aspen, as it has been from Sandbar Lake Provincial Park. Although it is provincially tracked, this species is inconspicuous and may be overlooked in the province. Three species, *B. laurocerasi*, *C. parvum,* and *O. pseudopallescens*, are also considered rare or very rare in southern Ontario (Wong and Brodo 1992). Within the province, *B. laurocerasi* has been collected mainly from the area directly surrounding the Great Lakes. Given the distance of this provincial park from this location (~200 km northwest), this observation is notable. Similarly, *C. chicitae* is only known from near Lake Superior in Ontario (Brodo *et al.* 2001). Geographic patterns found in previous reports of these species are likely affected by past collection efforts being almost exclusively in the area surrounding the Great Lakes, solidifying the need for further study in inland areas of northwestern Ontario. Overall, the species composition of the community found at Sandbar Lake Provincial Park reflects the boreal forest in the region; representative species include *P. aphthosa*, *V. pinastri*, and 17 species in the genus *Cladonia* (Brodo *et al.* 2001). The most common species in Sandbar Lake Provincial Park were *B. furcellata* and *P. canina*, which we collected six times each, at two and six collection sites, respectively. Both species are reported frequently from the province, as well.

Although the northwest region of Ontario is known for a high diversity of lichens, previously, only one study has been geographically focussed (an intensive study within a relatively small, delineated boundary such as within a provincial park of a few hundred ha as opposed to within the entire province or not in a delineated area) in the region, on the Slate Islands (C. Wetmore unpubl. data accessed through CNALH). Focussed studies in areas with delineated boundaries, such as ours, are important for establishing baseline data. Lichens are effective indicators of climate change and ecological integrity and, with a sound baseline, can be used to monitor changes in the local environment over time (McMullin *et al.* 2017).

Coefficients generated through a Sorensen–Dice comparison showed a low level of similarity between the lichen community at Sandbar Lake Provincial Park and two other provincial parks in Ontario. Given the distance and difference in climate and forest types among the parks, this result was not surprising. Awenda and Sandbanks Provincial Parks are over 1000 km southeast of Sandbar Lake Provincial Park and both border large freshwater bodies (Georgian Bay and Lake Ontario). Sandbar Lake is located within the boreal forest region, while Awenda and Sandbanks are in the Great Lakes–St. Lawrence forest region, which has a higher diversity of decidu-

ous trees. Both Awenda and Sandbanks Provincial Parks are smaller than our study area. Although the size of Sandbar Lake Provincial Park would likely relate to higher diversity of lichen species, access to most parts of this park are limited, with few roads and trails outside the campground. Access by trails and roads is also limited in some areas of Sandbanks; however, the small size of the park may make it easier to sample a greater proportion of its area. In contrast, Awenda has trail networks that can be used to access most portions of the park. Nonetheless, these parks were selected because they were the nearest areas with similar search efforts (McMullin and Lewis 2014; McMullin and Lendemer 2016).

Sandbar Lake Provincial Park is surrounded by resource extraction operations, especially timber harvesting. The park, therefore, provides protection for important habitats in the area. Expansions to the park have also facilitated increased ecosystem representativeness, and over time there is potential for mature or old-growth forests to develop—a habitat that is rare in this region (Ontario Parks 2012). Much of the current area of Sandbar Lake has experienced a variety of disturbances in recent history, including natural processes, such as wildfire, and anthropogenic ones, such as industrial-scale timber harvesting (Ontario Parks 2012). Forest management practices in northern Ontario have been shown to have direct effects on lichen community composition (e.g., herbicide contact, loss of microhabitats) and indirect effects (e.g., light exposure, tree species presence, changes in structural diversity, changes to available moisture; McMullin *et al.* 2013). As a result, previous disturbances in the park will have influenced the lichen biota present now. Our baseline data provide the first foundation that can be used to acknowledge and monitor future changes to the lichen community. Our results can also be used to compare with lichen communities on lands outside the park to better understand the effects on lichen biodiversity of resource extraction in the region.

Author Contributions

Writing – Original Draft Preparation: H.R.D. and R.T.M.; Writing – Review & Editing: R.T.M. and H.R.D.; Conceptualization: R.T.M.; Formal Analysis: H.R.D.; Investigation: H.R.D. and R.T.M.; Methodology: H.R.D. and R.T.M.; Project Administration: H.R.D. and R.T.M.; Resources: H.R.D. and R.T.M.

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SUPPLEMENTARY MATERIAL:

Appendix S1. Collection details of specimens.

The Canadian Field-Naturalist

Do turtle warning signs reduce roadkill?

David C. Seburn[1,*] and Hannah McCurdy-Adams[1,2]

[1]Canadian Wildlife Federation, 350 Michael Cowpland Avenue, Ottawa, Ontario K2M 2W1 Canada
[2]Current address: Wildlife Preservation Canada, 5420 Highway 6 North, Guelph, Ontario N1H 6J2 Canada
[*]Corresponding author: davids@cwf-fcf.org

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Abstract

Roadkill is a serious threat for many species of freshwater turtles. One of the most common road mitigation tools is wildlife warning signs to alert drivers. These warning signs have commonly been used for large mammals, although there is little evidence that they are effective in reducing roadkill. We tested the effectiveness of turtle warning signs at four known roadkill hotspots along a provincial highway in eastern Ontario and compared the results with four control sites on a nearby major road in a before-after-control-impact (BACI) study. We found 30 dead turtles in the four hotspots in 2017 before the signs were installed and 27 in 2018 after the signs were installed. The number of turtles killed on the road after the signs were installed did not change significantly ($\chi^2_1 = 1.1$, $P > 0.2$). Although turtle warning signs may alert some drivers, they should not be considered a replacement for more effective road mitigation tools, such as wildlife fencing and crossing structures.

Key words: Turtles; reptiles; road mitigation; wildlife signs; BACI design

Introduction

Roadkill is a major risk for many species of freshwater turtles (Gibbs and Shriver 2002; Steen and Gibbs 2004; Aresco 2005). It can lead to population declines (Gibbs and Shriver 2002) or male-biased populations from disproportionate roadkill of female turtles (Steen and Gibbs 2004; Dupuis-Désormeaux *et al.* 2017). Turtle populations are sensitive to any threat that increases the adult mortality rate (Congdon *et al.* 1993; Cunnington and Brooks 1996) and are extremely slow to rebound from declines (Keevil *et al.* 2018). As a result, roadkill can have a negative effect on turtle populations near roads (Rytwinski and Fahrig 2012).

Wildlife warning signs are one of the most commonly used tools to attempt to reduce roadkill, although there is little evidence that they are effective (Huijser *et al.* 2015). They can take the form of standard road signs as well as enhanced road signs with flashing lights or symbols (Pojar *et al.* 1975; Huijser *et al.* 2015). Most studies on the effectiveness of wildlife warning signs have found that they do not significantly reduce roadkill (e.g., Pojar *et al.* 1975; Coulson 1982; Bullock *et al.* 2011; but see Found and Boyce 2011). Most wildlife warning sign studies have focussed on large mammals, and we are unaware of any published studies on the effectiveness of standard wildlife signs on reducing turtle roadkill.

Given that all eight species of freshwater turtles that occur in Canada are listed as species at risk (Government of Canada 2019), it is important to assess whether turtle warning signs lead to a significant reduction in roadkill. To test the effectiveness of turtle signs (Figure 1) we examined roadkill before and after signs were installed at known hotspots in eastern Ontario. The importance of before-after-control-impact (BACI) research design has been stressed in evaluating the effectiveness of road mitigation strategies (Lesbarrères and Fahrig 2012); thus, we also compared roadkill rates with those on a control road over the same period.

Methods

As part of a larger project on turtle conservation, road surveys were conducted in eastern Ontario in 2017, and from those surveys four hotspots were identified. In spring 2018, the Ministry of Transportation installed standard turtle signs at these hotspots to help reduce roadkill. The four hotspots were located along provincial highway 15 north of Smiths Falls in Lanark County, along a section of road ~36 km in length (45.0°N, 76.0°W; Figure 2). Turtle warning signs were installed facing oncoming traffic at both ends of each hotspot. The signed road segments at each location averaged 1010 m (range 750–1675 m) in length. Daily traffic at these locations ranged from an

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FIGURE 1. Example of turtle sign installed by the Ministry of Transportation along provincial highway 15 in eastern Ontario in May 2018. Photo: David Seburn.

annual average daily traffic of 4950 to 9400 vehicles (Ministry of Transportation 2019).

The four control road segments were located along Roger Stevens Drive east of Smiths Falls in Lanark County, along a section of road ~28 km in length (Figure 2). Highway 15 and Roger Stevens Drive intersect in Smiths Falls and the two roads are less than 25 km apart at any point. Each control segment was 1000 m in length and was selected based on the presence of at least four roadkilled turtles during 2017. Daily traffic in the four control segments varied by section, and ranged from an annual average daily traffic volume of 2860 to 3900 vehicles (roads department, Lanark County unpubl. data). Both the control and impact roads were paved, two-lane roads, with a posted speed limit of 80 km/h, although this limit was frequently exceeded by drivers (D.C.S. and H.M.-A. pers. obs.).

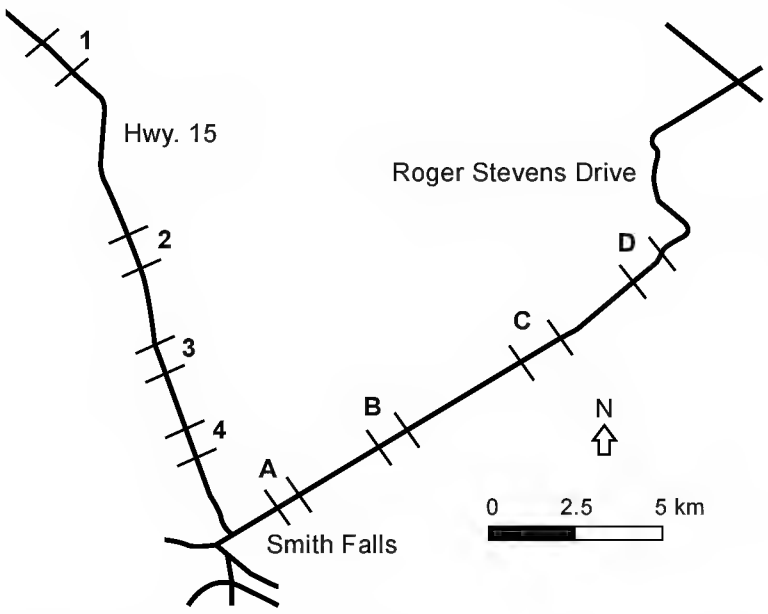

FIGURE 2. Location of two roads used in test of the effectiveness of turtle signs in eastern Ontario in 2017 and 2018. Roadkill hotspots were located along provincial highway 15 and are numbered 1–4. Turtle signs were installed at each end of all four hotspots in spring 2018. Four segments of road along Roger Stevens Drive, labelled A–D, served as control sections.

Road surveys were usually conducted with at least two people in the vehicle, but on some occasions, only one person conducted a road survey. Surveys were conducted during the day, typically from 0900 to 1600. Roads were surveyed by driving at ~50–60 km/h and scanning the road surface and road shoulders for dead turtles. The location of each roadkilled turtle was recorded using a handheld global positioning system unit (eTrex or eTrex 20×, Garmin Ltd., Olathe, Kansas, USA) with a spatial accuracy of at least ± 5 m. All dead turtles were removed from the road or road shoulder to prevent double counting on a subsequent survey. Road surveys were conducted approximately weekly from May until early September in 2017 and 2018. Both control and impact roads were typically surveyed on the same day.

The turtle warning signs were installed at the end of May 2018. Only dead turtles found in 2018 after the signs were installed were included in the analysis for both control and impact roads. Similarly, for 2017, only turtles from after the end of May were included so that the same period in both years was compared. In addition, all live turtles found on the road were excluded to examine only the effect of the road signs on turtle mortality. Live turtles made up <10% of all turtles found on roads. This is as expected, as, if turtles successfully cross a road, they are only present for a few minutes and would only be detected if the crossing coincided with the survey.

A chi-squared 2×2 contingency table was used to compare differences in the number of turtles in 2017 and 2018 for both roads (Minitab 8.3; Minitab Inc., State College, Pennsylvania, USA). The turtles from all four hotspots were pooled to prevent pseudoreplication (Hurlbert 1984) and the two years compared. Similarly the four control road segments were pooled and the two years compared. Statistical significance was defined as $P < 0.05$.

Results

Three species of turtles were found during surveys: Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), and Blanding's Turtle (*Emydoidea blandingii*). We found 30 dead turtles in the four hotspots in 2017 before the signs were installed, and 27 in 2018 after the signs were installed. In the four control sections, we found 19 dead turtles in 2017 and 26 in 2018 after the signs were installed

along the other road. There was no statistically significant difference in the number of turtles found before or after the signs were installed (Table 1; $\chi^2_1 = 1.1$, $P > 0.2$).

Discussion

Our road surveys likely did not detect all of the turtles killed on the roads, as they were conducted approximately weekly and turtle carcasses along roads may not persist that long (Santos *et al.* 2011). In addition, compared with walking surveys, driving surveys may fail to detect some carcasses (Santos *et al.* 2016). There is no reason to assume that carcass persistence or detectability would have differed significantly between the two years, and survey methods and survey frequency were the same in both years.

There were similar numbers of roadkilled turtles in the control road sections in both years, suggesting that roadkill numbers in the impact road sections would also have been similar in both years without the presence of any mitigation. Thus, any significant changes in roadkill numbers in the impact road sections between 2017 and 2018 should be attributable to the road signs. The lack of any significant decrease in roadkill indicates that the signs were not effective. A larger sample size would have increased our chances of detecting a statistically significant difference in the amount of roadkill, if one existed. Nonetheless, a decrease of only 10% in roadkill in 2018 from 2017 is not indicative of effective mitigation, as wildlife barriers and crossing structures can reduce roadkill by more than 90% (Dodd *et al.* 2004). Any road mitigation strategy that results in only a 10% reduction in roadkill should be considered a failure.

Wildlife warning signs are one of the most commonly installed road mitigation tools (Huijser *et al.* 2015), likely because of their low cost. However, despite their wide use, there is little evidence that such warning signs are effective at reducing roadkill. Few drivers are even aware of such warning signs. In one study, only 5–10% of drivers who were stopped 200 m after passing a warning sign were able to recall the sign (Drory and Shinar 1982).

For warning signs to be effective, they should result in drivers reducing their speed. Animated deer (*Odocoileus* spp.) warning signs have led to a reduction in speed, but only by <5 km/h (Pojar *et al.* 1975). Similarly, camel (*Camelus* spp.) warning signs have resulted in a decline in vehicle speed, but only by 3–7 km/h (Al-Ghamdi and AlGadhi 2004). Moose (*Alces americanus*) warning signs reduced driving speeds by only 1.5 km/h in a driving simulator (Jägerbrand *et al.* 2018). Greater speed reductions (~10 km/h) have occurred when deer carcasses were placed next to warning signs to emphasize the reality of the threat (Pojar *et al.* 1975). The effectiveness of animal warning signs on driving speed may also decline over time as drivers become habituated to the signs (Pojar *et al.* 1975; Khalilikhah and Heaslip 2017). Hence, it seems that even large-mammal warning signs may only have a small effect on vehicle speeds, even though collisions can result in the injury or death of the driver (e.g., Conover *et al.* 1995; Niemi *et al.* 2017).

Ultimately, the main issue is whether animal warning signs result in a reduction in collisions and roadkill. Deer crossing signs did not reduce the number of deer killed in Colorado (Pojar *et al.* 1975), but deer collisions were reduced, at least for the first year, after warning signs were installed at known hotspots in the city of Edmonton, Alberta (Found and Boyce 2011). Temporary, flashing warning signs installed at known deer migration locations resulted in a significant reduction in vehicle collisions, but this effect lessened during the second year of the study (Sullivan *et al.* 2004). Warning signs were also not effective at reducing roadkill of kangaroos in Australia (Coulson 1982; Shima *et al.* 2018), mammals and birds along a major road in South Africa (Bullock *et al.* 2011), or snakes in Illinois (Shepard *et al.* 2008).

Enhanced warning signs may be effective under some limited circumstances. Diamond-backed Terrapins (*Malaclemys terrapin*) suffer high rates of road mortality during nesting forays, which are associated with diurnal high tides (Crawford *et al.* 2014). Flashing warning signs installed but only activated for a 2-h period each day corresponding to the diurnal high tide during the nesting season, significantly reduced Diamond-backed Terrapin roadkill (Crawford *et al.* 2018). It is also possible that wildlife warning signs may be more effective along roads with a lower speed limit as speed limit is often positively correlated with roadkill (Farmer and Brooks 2012).

Although wildlife warning signs may not significantly reduce roadkill, they can still be valuable within a comprehensive mitigation strategy for public education and sending a message that roadkill of wildlife is a serious issue. Wildlife warning signs should not replace more effective road mitigation tools such as wildlife fencing and crossing structures (e.g., Dodd *et al.* 2004; Aresco 2005; Baxter-Gilbert *et al.* 2015; Crawford *et al.* 2017).

TABLE 1. Results of 2×2 chi-squared contingency table comparing the observed number of dead turtles on the control and impact roads, both before and after turtle signs were installed.

Site	Roadkill (expected value)	
	Before	After
Impact (with signs)	30 (27.4)	27 (29.6)
Control (no signs)	19 (21.6)	26 (23.4)

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Surveys for terrestrial gastropods in the Kootenay region of British Columbia, with new records and range extensions

Kristiina Ovaska[1,*], Lennart Sopuck[1], and Jennifer Heron[2]

[1]Biolinx Environmental Research Ltd., 1759 Colburne Place, North Saanich, British Columbia V8L 5A2 Canada
[2]Ministry of Environment and Climate Change Strategy, Conservation Science Section, Suite 200, 10428 153rd Street, Surrey, British Columbia V3R 1E1 Canada
*Corresponding author: ke.ovaska@gmail.com

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Abstract

The northern Columbia River basin, extending from the Kootenay region in British Columbia southward to the Idaho panhandle and northwestern Montana, contains a unique terrestrial gastropod fauna, but in Canada few surveys have specifically targetted this group. Here we report on terrestrial gastropods detected during surveys of 314 sites distributed in five biogeoclimatic zones across the Kootenay region. The surveys occurred on 65 days over seven years from 2007 to 2015, usually in September–October. We detected 45 taxa identified to species, belonging to 33 genera; micro-snails of the genus *Vertigo* (apart from *Vertigo ovata*) were combined into a single category, and snails belonging to Succineidae were not identified further. Regionally endemic species previously reported from the region included Western Banded Tigersnail (*Anguispira kochi occidentalis*), Coeur d'Alene Oregonian (*Cryptomastix mullani*), Rocky Mountainsnail (*Oreohelix strigosa*), Subalpine Mountainsnail (*Oreohelix subrudis*), and Pale Jumping-slug (*Hemphillia camelus*), which was widespread across the region. Magnum Mantleslug (*Magnipelta mycophaga*), the distribution of which extends beyond the Kootenay region, was detected at several widely spaced sites. Two species new to Canada were detected, Pygmy Slug (*Kootenaia burkei*) and Sheathed Slug (*Zacoleus idahoensis*), both of which were subsequently assessed to be of conservation concern both provincially and nationally. Other notable observations included the detection of Fir Pinwheel (*Radiodiscus abietum*), a regional endemic, which has been previously reported only once, and three species common in coastal forests but not previously reported from the region: Pacific Banana Slug (*Ariolimax columbianus*), Robust Lancetooth (*Haplotrema vancouverense*), and Northwest Hesperian (*Vespericola columbianus*). Further surveys, especially at higher elevations, may reveal other additional or unusual species.

Key words: Terrestrial gastropods; new distribution records; Kootenays; inventory

Introduction

Mesic forests of the northern Columbia River basin support many unique plants and animals and species with vicarious distributions, separated from their Pacific coastal counterparts by 300 km or more of arid landscapes (Brunsfeld *et al.* 2001). This unique area extends from southeastern British Columbia (BC) and northeastern Washington southward through the Idaho Panhandle into northwestern Montana. In BC, it encompasses the Kootenay region, which supports a diverse gastropod fauna, including species that are found nowhere else in Canada (Forsyth 1999, 2004). Few studies have specifically targetted this group, and until recently our knowledge of it was based on brief historical accounts, records in Pilsbry's (1939, 1940, 1946, 1948) monograph, and largely serendipitous observations (reviewed by Forsyth 1999). Recent targetted surveys include the Royal British Columbia Museum's Living Landscape expedition (Forsyth 1999) and surveys by Nekola *et al.* (2011) in the central Selkirk Mountains and their vicinity in support of a proposed Selkirk Mountains Caribou Park. Increased survey efforts in this biologically rich area continue to provide new records and document species new to the province.

Here we report on surveys targetting terrestrial gastropods in southeastern BC during seven annual surveys from 2007 to 2015 (no surveys were conducted in 2011–2013), including documentation of two species of slugs new to Canada. The surveys were in support of conservation assessments by the province of BC and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and focussed on species deemed to be rare or at risk.

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Focal species initially included the snails Western Banded Tigersnail (*Anguispira kochi occidentalis*), Coeur d'Alene Oregonian (*Cryptomastix mullani*), and mountainsnail (*Oreohelix*) species, and the slugs Magnum Mantleslug (*Magnipelta mycophaga*) and Pale Jumping-slug (*Hemphillia camelus*). Two species, Pygmy Slug (*Kootenaia burkei*) and Sheathed Slug (*Zacoleus idahoensis*), were added after their discovery as part of this study in 2007 and 2009, respectively. The primary objective was to clarify distributions of the focal species. A secondary objective was to investigate the presence of possible undocumented species of the northern Columbia basin fauna, the distributions of which may extend northward across the international border into Canada.

Study Area

This study was conducted in the Kootenay region of southeastern BC, bounded by the Rocky Mountains to the east, the Canada–United States (USA) border to the south, Shuswap/Okanagan Highlands to the west, and the 51.6° latitude to the north (Figure 1). The area consists of a series of rugged northwest–southeast oriented mountain ranges (Rocky, Purcell, Selkirk, and Monashee), separated by large valleys, rivers, and lakes. The varied terrain and climate, which can change across short distances, result in a diversity of ecosystems, which have strong influences on terrestrial gastropod distributions.

The study area overlaps five of 14 biogeoclimatic zones in BC (BECP n.d.). A zone is classified according to the unique assemblage and distribution of climax and late-seral plant communities, energy flow, nutrient-cycling and soils, topography, and regional climate of a geographic area. Biogeoclimatic zones of the study area include high elevation Interior Mountain-heather Alpine (IMA) and Engelmann Spruce (*Picea engelmannii* Engelmann)–Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall) (ESSF) zones; mid-elevation Interior Cedar–Hemlock (ICH) and

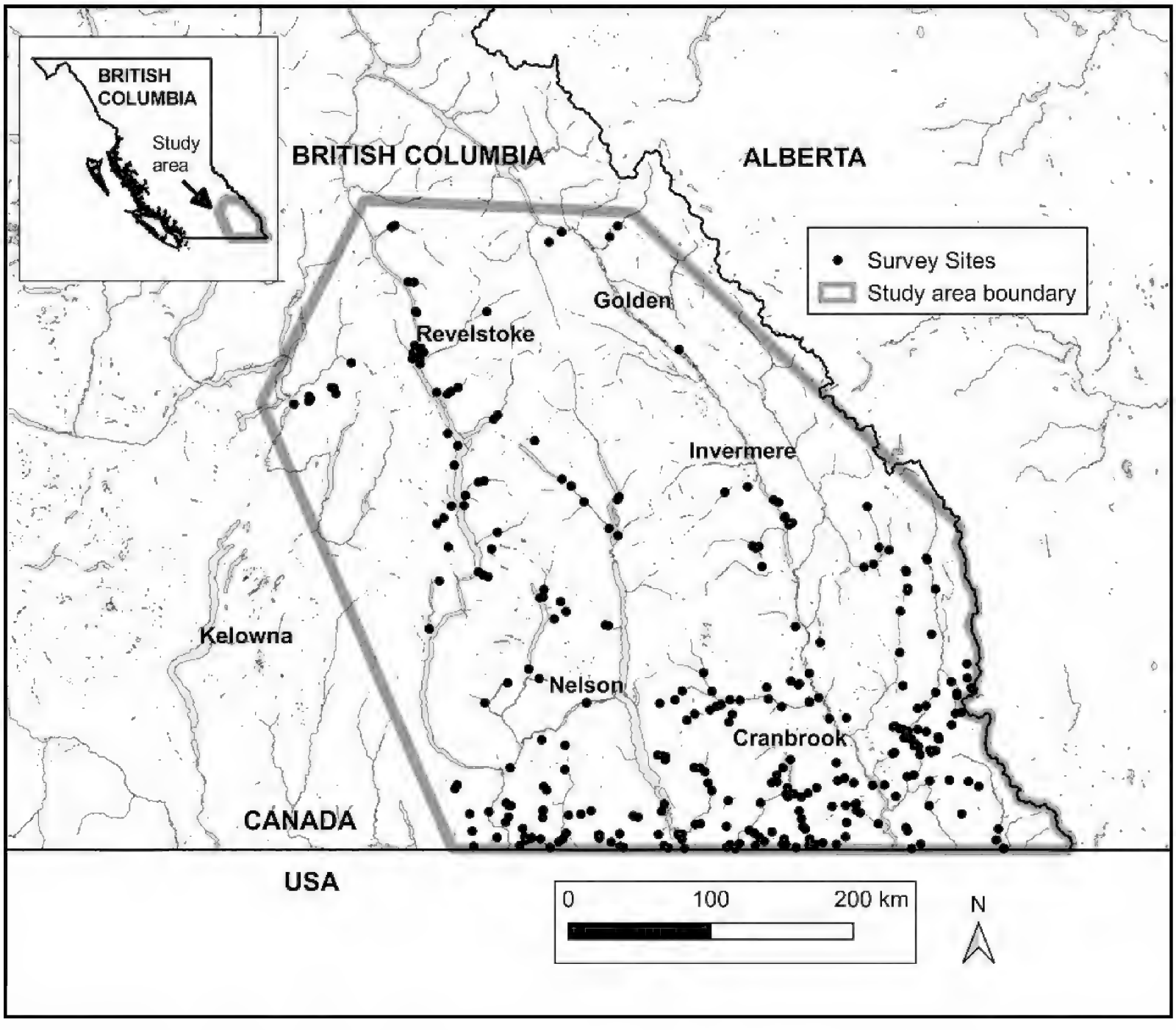


FIGURE 1. Location of the study area and sites surveyed in 2007–2015 in southeastern British Columbia.

Montane Spruce (MS) zones; low-elevation Interior Douglas Fir (*Pseudotsuga menziesii* (Mirbel) Franco) (IDF) zone; and Ponderosa Pine (*Pinus ponderosa* Douglas ex Lawson & C. Lawson) zone (MacKillop *et al.* 2018; BECP n.d.). Of the forested zones, the ESSF and ICH zones tend to have wet climates, whereas the MS and IDF zones tend to be dry. Moist Engelmann Spruce–Subalpine Fir forests dominate the higher elevations; White Spruce (*Picea glauca* (Moench) Voss), Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and Western Redcedar (*Thuja plicata* Donn ex D. Don) forests dominate the wetter low- to mid-elevations; Lodge-pole Pine (*Pinus contorta* Douglas ex Loudon), Western Larch (*Larix occidentalis* Nuttall), and Douglas Fir forests occur on the drier mountain slopes; Ponderosa Pine and grasslands occur in the dry, low-elevation valley bottoms.

In recent years, logging, wildfires, hydroelectric reservoirs, and Mountain Pine Beetle (*Dendroctonus ponderosae*) epidemics have disturbed large areas of forest in the study area. The effects of cattle ranching are localized, occurring mainly in grassland and open forest habitats at low elevations. Human developments are relatively sparse, with settlements and farming occurring mainly in low-elevation river valleys, such as along the Columbia and Kootenay rivers. Several federal and provincial parks contain large areas of relatively undisturbed forest, but these are mostly restricted to higher elevations.

Methods

Survey sites and effort

We surveyed 314 sites, which were at least 500 m apart and distributed across the study area (Figure 1, Appendix S1); geopositions were recorded with a handheld global positioning system unit (GPSMAP 60Cx; Garmin, Olathe, Kansas, USA). Survey efforts focussed on BC Crown forestry lands, which were accessed through logging roads that crisscrossed the area. The sites also included provincial parks ($n = 5$), national parks ($n = 4$), Ktunaxa First Nation reserve lands ($n = 17$), municipal lands ($n = 6$), and private lands used for forestry, ranching, or recreation ($n = 22$). Most sites were searched only once, but repeated surveys were conducted at eight sites. The total time spent intensively searching for gastropods was 347 person-hours, with the median survey time one hour per site during 65 days over a seven-year period.

Survey dates, conditions, and methods

The surveys took place on the following dates: 10–16 July and 22–27 September 2007; 3–8 September and 4–7 October 2008; 6–9 October 2009; 20 July and 6–16 September 2010; 20–25 September 2013: 15–29 September 2014; and 20–25 September 2015. It rained during 16.5% of the surveys, and the median ambient temperature (measured at ground level at the start of the survey) was 11°C in September–October and 24°C in July.

To locate gastropods, usually two observers (K.O. and L.S.) walked along meandering transects through habitat deemed suitable for gastropods and examined decaying logs, piles of bark, stumps, rocks, other moist refuges, and accumulations of leaf litter, focussing on points where concentrations of such features were present. Most surveys took place during daylight hours, but a few ($n = 5$) took place on wet nights after dark to detect gastropods active on the surface. At night, we used high-watt flashlights to scan the ground surface and tree trunks while walking along trails or traversing suitable habitat and/or driving slowly along side-roads using fog lights to illuminate the road surface.

Identification and vouchers

We identified all gastropods found, in some cases only to genus (such as micro-snails of *Vertigo*), based on external characteristics. Identification was usually done in the field, but we collected samples of small snails and confirmed identification in the laboratory of the Royal British Columbia Museum (RBCM) using a dissecting microscope. Three specimens of *Hemphillia* were sent to Lyle Chichester to confirm identity through examination of distal reproductive anatomy; several species of *Hemphillia* occur south of the border in the USA and have not been reported from Canada. Identification was based on descriptions in Pilsbry (1940, 1948), Forsyth (2004), and Burke (2013). Nomenclature for species followed Forsyth (2004) and, for families, Bouchet *et al.* (2017). Voucher specimens were deposited in collections at the RBCM (Appendix S2); photographic vouchers were retained in personal collections by the authors.

Results

The surveys resulted in the detection of 45 taxa identified to species, belonging to 33 genera (Table 1). Micro-snails of the genus *Vertigo* (apart from Ovate Vertigo, *Vertigo ovata*) were combined into a single category, which included nominal taxa of *Vertigo columbiana*, *Vertigo cristata*, *Vertigo gouldii*, *Vertigo modesta*, and possibly other taxa (vouchers at RBCM). Collections of *Vertigo* from British Columbia await re-examination in light of the recent revision of the genus (Nekola *et al.* 2018). Snails of the family Succineidae were not identified below this level because of complications associated with identification based on shell morphology.

The most commonly encountered taxa were Brown Hive (*Euconulus fulvus*, 57% of sites surveyed), Forest Disc (*Discus whitneyi*, 45%), *Vertigo* species group

Table 1. Terrestrial gastropod species detected during surveys in the Kootenay region, 2007–2015. See Appendix S1 for coordinates and description of sites. Site numbers 104 and 295 were not used.

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total (n = 314)	% of all sites	No. of individuals (no. dead)
	ESSF (n = 37)	ICH (n = 192)	IDF (n = 33)	MS (n = 39)	PP (n = 13)			
AGRIOLIMACIDAE								
Deroceras laeve (Meadow Slug)	—	19, 42, 60, 63, 70, 87, 92, 93, 102, 122, 150, 163, 192, 194, 197, 281 (8.3)	168, 169, 182, 225, 232, 234, 242, 271 (24.2)	229, 233, 243, 246, 257, 307 (15.4)	202, 214, 216, 218, 224, 227, 251 (53.8)	37	11.7	130
Deroceras invadens (Tramp Fieldslug)*†	—	—	—	292 (2.6)	—	1	0.3	9
Deroceras reticulatum (Grey Fieldslug)*	—	1, 66, 68, 87, 93, 99, 130, 226, 263, 268, 274, 275, 280, 281, 282, 294 (8.3)	136, 168, 195, 299 (12.1)	181, 223, 236, 277, 303, 304 (15.4)	202, 206, 208, 216 (30.8)	30	9.5	204
ANADENIDAE								
Kootenaia burkei (Pygmy Slug)	115, 132 (5.4)	49, 50, 62, 67, 71, 76, 80, 81, 83, 84, 86, 90, 97, 101, 106, 125, 131, 144, 146, 147, 150, 152, 158, 164, 167, 174, 179, 180, 185, 187, 188. 192, 193, 196, 200, 205, 207, 221, 228 (20.2)	—	220, 230, 237 (7.7)		44	14.0	128
Prophysaon andersonii (Reticulate Taildropper)	17 (2.7)	1, 10, 19, 23, 41, 44, 47, 48, 58, 60, 68, 69, 80, 87, 93, 99, 101, 141, 165, 174, 178, 180, 207, 263, 268 (13.0)	—	—	—	26	8.3	249
ARIOLIMACIDAE								
Ariolimax columbianus (Pacific Banana Slug)	—	10, 17 (1.0)	—	—	—	2	0.6	14
Magnipelta mycophaga (Magnum Mantleslug)	115, 267, 293 (8.1)	13, 18, 25, 160, 178, 252 (3.1)	—	220 (2.6)		10	3.2	14
Zacoleus idahoensis (Sheathed Slug)	210, 231 (5.4)	71, 158, 180, 198, 200, 207, 228 (3.6)	—	—	—	9	2.9	16
ARIONIDAE								
Arion circumscriptus (Brown-banded Arion)*	—	1, 47, 60, 84, 92, 199, 274, 275, 282, 294 (5.2)	272 (3.0)	181, 277 (5.1)	—	13	4.1	111
Arion intermedius (Hedgehog Arion)*	—	23, 66 (1.0)	—	—	—	2	0.6	11
Arion rufus (Chocolate Arion)*	—	14, 23, 29, 48, 59, 92, 97, 105, 199, 207 (5.2)	—	—	—	10	3.2	39
Arion sp. (unidentified juveniles)*	—	33, 66, 91, 93, 97, 112, 199 (3.6)	—	—	—	7	2.2	30
BINNEYIDAE								
Hemphillia camelus (Pale Jumping-slug)	17, 45, 107, 108, 109, 120, 121, 143, 145, 217, 231, 245, 289, 293 (37.8)	12, 18, 20, 26, 28, 29, 31, 35, 36, 38, 39, 42, 48, 61, 67, 69, 72, 75, 80, 81, 82, 83, 91, 94, 99, 101, 113, 114, 116, 122, 123, 124, 125, 127, 129, 131, 133, 134, 135, 139, 154, 155, 156, 160, 161, 162, 163, 166, 167, 176, 178, 179, 180, 184, 187, 188, 193, 194, 207, 211, 226, 228, 252, 259 (33.2)	171, 172 (6.1)	181, 235, 237, 238, 244 (12.8)	—	85	27.0	261

TABLE 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total ($n = 314$)	% of all sites	No. of individuals (no. dead)
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)			
CHAROPIDAE								
Radiodiscus abietum (Fir Pinwheel)	—	85, 91 (1.0)	—	—	—	2	0.6	2
COCHLICOPIDAE								
Cochlicopa lubrica (Glossy Pillar)	—	92, 130 (1.0)	190 (3.0)	—	—	3	1.0	4
DISCIDAE								
Anguispira kochi occidentalis (Western Banded Tigersnail)	—	57, 61, 64, 65, 67, 71, 76, 78, 79, 95, 96, 99, 112, 113, 123, 126, 131, 134, 137, 141, 146, 159, 163, 167, 174, 178, 180, 193, 207, 221 (15.5)	182 (3.0)	—	—	31	9.8	276 (102)
Discus shimekii (Striate Disc)	—	81, 275, 282 (1.6)	272 (3.0)	292, 300, 315, 316 (10.3)	—	8	2.5	82
Discus whitneyi (Forest Disc)	2, 115, 121, 245, 267 (13.5)	7, 10, 13, 14, 18, 19, 20, 22, 23, 26, 32, 33, 36, 37, 46, 49, 50, 51, 54, 55, 58, 60, 61, 62, 63, 64, 65, 66, 67, 69, 70, 73, 76, 78, 79, 80, 81, 82, 84, 85, 86, 87, 89, 90, 92, 93, 95, 96, 97, 99, 101, 102, 106, 113, 114, 116, 117, 119, 122, 123, 126, 129, 134, 146, 147, 148, 149, 151, 153, 154, 164, 166, 174, 176, 178, 179, 180, 185, 187, 192, 196, 199, 200, 207, 212, 221, 222, 228, 254, 259, 274, 280, 282, 286, 287, 294 (49.7)	168, 169, 173, 175, 182, 183, 186, 189, 191, 232, 234, 239, 241, 242, 270, 271, 272, 285, 299 (57.6)	157, 181, 230, 233, 237, 238, 244, 246, 250, 277, 283, 292, 303, 304, 305, 308, 309 (43.6)	202, 214, 218, 218, 227 (38.5)	142	45.1	780 (20)
Discus sp. (juveniles)	—	33, 42, 72, 98, 111, 112, 131, 144, 161, 163, 167, 180, 219, 282 (7.3)	—	181, 229 (5.1)	—	16	5.1	60
EUCONULIDAE								
Euconulus fulvus (Brown Hive)	2, 9, 45, 132, 217, 245, 260, 262, 265, 298, 312 (29.7)	7, 10, 13, 14, 19, 20, 22, 23, 26, 28, 29, 33, 35, 36, 37, 41, 47, 49, 51, 52, 54, 55, 56, 57, 58, 60, 63, 64, 65, 66, 68, 69, 70, 71, 72, 75, 76, 78, 79, 80, 81, 84, 85, 86, 87, 88, 89, 91, 92, 93, 95, 97, 99, 100, 101, 102, 106, 111, 112, 113, 114, 116, 117, 118, 119, 126, 128, 129, 131, 135, 138, 139, 146, 148, 149, 150, 151, 152, 153, 154, 159, 160, 161, 162, 163, 165, 166, 167, 174, 176, 180, 184, 185, 188, 192, 193, 196, 198, 199, 200, 205, 207, 211, 222, 226, 228, 252, 254, 259, 280, 281, 282, 294, 296 (59.1)	136, 168, 175, 183, 189, 190, 191, 225, 234, 239, 240, 242, 247, 253, 255, 271, 285, 299 (54.5)	157, 181, 220, 229, 230, 233, 235, 236, 237, 238, 244, 246, 250, 257, 258, 277, 283, 292, 300, 302, 303, 304, 305, 307, 308, 309, 311, 313, 315 (74.4)	202, 208, 214, 215, 216, 218, 227, 249 (61.5)	180	57.1	659
Euconulus aff. *alderi* (Marsh Hive)‡	—	27, 37 (1.0)	168 (3.0)	—	214, 216 (15.4)	5	1.6	25
GASTRODONTIDAE								
Nesovitrea binneyana (Blue Glass)	—	77 (0.5)	169, 270, 272 (9.1)	246 (2.6)	—	5	1.6	13

Table 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total ($n = 314$)	% of all sites	No. of individuals (no. dead)
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)			
Nesovitrea electrina (Amber Glass)	260 (2.7)	13, 20, 22, 37, 58, 60, 89, 102, 119, 282 (5.2)	168, 183, 190, 191, 271 (15.2)	—	216, 227 (15.4)	18	5.7	53
Nesovitrea sp. (*N. electrina* or *N. binneyana*)	—	11, 19, 23, 26, 28, 31, 32, 33, 36, 50, 53, 58, 61, 64, 65, 66, 69, 79, 85, 86, 90, 91, 114, 123, 125, 149, 153, 166, 228 (15.0)	182, 232 (6.1)	181, 304 (5.1)	208, 214 (15.4)	35	11.1	67
Striatura pugetensis (Northwest Striate)	—	67, 95, 200 (1.6)	—	—	—	3	1.0	7
Zonitoides arboreus (Quick Gloss)	9, 266, 267 (8.1)	11, 19, 23, 32, 37, 47, 50, 51, 53, 54, 57, 58, 60, 61, 63, 64, 65, 67, 69, 71, 77, 80, 85, 86, 89, 91, 96, 99, 100, 101, 102, 113, 116, 118, 123, 129, 138, 150, 162, 163, 165, 166, 184, 196, 199, 226, 228, 252, 259, 280, 281 (26.4)	168, 173, 182, 183, 186, 190, 191, 204, 225, 232, 247, 270, 271 (39.4)	181, 201, 220, 229, 233, 238, 246, 277, 303, 304, 313 (28.2)	208, 215, 216, 227, 256 (38.5)	83	26.3	230
Zonitoides nitidus (Black Gloss)	—	23, 52, 59, 73, 74, 78, 87, 97, 102, 116, 165, 286, 291, 294 (7.3)	169, 175, 189, 234, 253 (15.2)	236, 246, 250, 258, 283, 284, 288, 300 (20.5)	206, 214, 224, 249, 251 (38.5)	32	10.2	134
Zonitoides sp. (*Z. arboreus* or *Z. nitidus*)	—	26, 27, 33, 35, 54, 59, 66, 92, 111, 160, 161, 165, 174, 228, 254, 279 (8.3)	182 (3.0)	244, 316 (5.1)	224 (7.7)	20	6.3	33
HAPLOTREMATIDAE								
Haplotrema vancouverense (Robust Lancetooth)	—	68, 82, 87, 90, 97 (2.6)	—	—	—	5	1.6	8
HELICIDAE								
Cepaea nemoralis (Grovesnail)*	—	1, 48, 105 (1.6)	—	—	—	3	1.0	71
LIMACIDAE								
Limax maximus (Giant Gardenslug)*	17 (2.7)	1, 14, 23, 105, 112, 137, 207, 278, 280, 281 (5.2)	195 (3.0)	—	—	12	3.8	29
OREOHELICIDAE								
Oreohelix strigosa (Rocky Mountainsnail)	265, 312 (5.4)	47, 69, 71, 73, 74, 77, 113, 130, 134, 137, 138, 141, 142, 174, 180, 196, 223, 259, 269, 274, 278, 279, 280, 282, 286, 290, 291, 294 (14.5)	255, 272, 273, 299 (12.1)	258, 261, 277, 288, 300, 303, 304, 307, 308, 314, 315, 316 (30.8)	—	46	14.6	1566 (948)
Oreohelix subrudis (Subalpine Mountainsnail)	267 (2.7)	278 (0.5)	—	302, 304 (5.1)	—	4	1.3	11 (10)
Oreohelix sp.	—	70, 71, 91, 123 (2.1)	239 (3.0)	220 (2.6)	—	6	1.9	8

TABLE 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total ($n = 314$)	% of all sites	No. of individuals (no. dead)
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)			
POLYGYRIDAE								
Allogona ptychophora (Idaho Forestsnail)	267 (2.7)	1, 14, 22, 23, 32, 35, 38, 39. 47, 48, 50, 54. 68, 71, 73, 78, 93, 102, 112, 126, 130, 135, 137, 138, 140, 141, 142, 159. 162, 163, 166, 174, 196, 200, 207, 221, 223, 259, 269, 274, 278, 279, 280, 282, 286, 290, 294 (24.5)	255, 270, 272, 273 (12.1)	220, 230, 261, 277, 300 (12.8)	216, 218, 227 (23.1)	59	18.8	1011 (558)
Cryptomastix mullani (Coeur d'Alene Oregonian)	—	1, 14, 23, 26, 28, 31, 33, 47, 50, 53, 57, 61, 64, 65, 66, 67, 69, 70, 71, 73, 74, 76, 78, 79, 84, 89, 105, 123, 126, 137, 138, 140, 142, 159, 161, 163, 196, 199 (19.7)	—	277 (2.6)	—	39	12.4	247 (64)
Vespericola columbianus (Northwest Hesperian)	—	87 (0.5)	—	—	—	1	0.3	1
PRISTILOMATIDAE								
Pristiloma chersinella (Black-foot Tightcoil)	9, 115, 120 (8.1)	23, 111, 122, 296 (2.1)	—	—	—	7	2.2	12
PUNCTIDAE								
Paralaoma servilis (Pinhead Spot)	—	50 (0.5)	189 (3.0)	—	—	2	0.6	6
Punctum randolphii (Conical Spot)	115, 231, 260, 297 (10.8)	22, 23, 44, 65, 74, 78, 86, 95, 96, 99, 100, 125, 128, 129, 131, 146, 147, 149, 151, 160, 164, 174, 176, 178, 192, 196, 200, 205, 252, 281, 296 (16.1)	183, 204, 225, 234, 270 (15.2)	237, 304, 309, 311 (10.3)	224, 227 (15.4)	46	14.6	80
Punctum sp.	—	19, 28, 53, 57, 58, 60, 68, 84, 98, 167, 221 (5.7)	—	—	—	11	3.5	37
SUCCINEIDAE								
Succineid spp.	—	—	—	—	214, 227 (15.4)	2	0.6	4
THYSANOPHORIDAE								
Microphysula ingersollii (Spruce Snail)	107, 108, 231, 245, 260, 267, 293, 297, 310, 312 (27.0)	1, 7, 10, 11, 31, 33, 36, 42, 46, 49, 50, 55, 60, 64, 68, 72, 73, 74, 76, 79, 80, 81, 85, 87, 89, 97, 113, 125, 126, 128, 131, 139, 144, 147, 149, 150, 151, 152, 160, 164, 184, 188, 192, 193, 194, 196, 198, 200, 205, 211, 219, 252, 254, 281, 291 (28.5)	204, 225, 240, 242, 270, 285 (18.2)	220, 233, 235, 236, 244, 250, 257, 258, 277, 304, 311 (28.2)	208, 215, 218 (23.1)	85	27.0	184
VALLONIDAE								
Planogyra clappi (Western Flat-whorl)	—	50 (0.5)	—	—	—	1	0.3	6
Vallonia cyclophorella (Silky Vallonia)	—	142, 165, 174 (1.6)	—	246 (2.6)	—	4	1.3	11
Vallonia excentrica (Iroquois Vallonia)*	—	—	195 (3.0)	—		1	0.3	6

Table 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total ($n = 314$)	% of all sites	No. of individuals (no. dead)
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)			
Zoogenetes harpa (Boreal Top)	—	84 (0.5)	—	—	—	1	0.3	10
VERTIGINIDAE								
Columella columella (Cylindrical Mellow Column)	—	23, 75, 79, 275 (2.1)	—	309 (2.6)	—	5	1.6	9
Columella sp.	—	49, 78 (1)	—	311 (2.6)	—	3	1.0	10 (8)
Vertigo ovata (Ovate Vertigo)	—	27 (0.5)	203, 204 (6.1)	—	—	3	1.0	7
Vertigo spp. (several taxa except *V. ovata*)	2, 121, 217, 245, 260, 297, 298 (18.9)	1, 7, 10, 19, 20, 23, 28, 29, 31, 36, 44, 49, 50, 51, 54, 55, 56, 57, 60, 66, 68, 72, 75, 80, 81, 84, 85, 91, 92, 94, 98, 101, 111, 113, 116, 117, 129, 131, 133, 135, 144, 147, 149, 150, 152, 155, 156, 160, 161, 164, 167, 176, 184, 187, 188, 192, 193, 196, 197, 205, 207, 211, 219, 221, 222 (33.7)	168, 169, 182, 225, 270, 271 (18.2)	229, 230, 235, 237, 244, 250, 301, 305, 307, 308, 309, 313 (30.8)	—	90	28.6	324
VITRINIDAE								
Vitrina pellucida (Western Glass-snail)	109, 245, 265, 266, 297 (13.5)	1, 11, 23, 31, 33, 36, 41, 46, 49, 50, 60, 64, 66, 78, 80, 87, 94, 99, 131, 134, 138, 140, 148, 164, 165, 187, 207, 222, 252, 280, 294 (16.1)	168, 182, 183, 225, 234, 242, 272, 273, 299 (27.3)	181, 292, 302, 303, 304, 305, 308 (17.9)	206, 215, 218, 276 (30.8)	56	17.8	163

Note: BEC = Biogeoclimatic Ecosystem Classification, ESSF = Engelmann Spruce–Subalpine Fir, ICH = Interior Cedar–Hemlock, IDF = Interior Douglas Fir, MS = Montane Spruce, PP = Ponderosa Pine.

*Introduced species of Eurasian origin.

†Forsyth (2004) applied the name *Deroceras panormitanum* to this species. Subsequently, Reise *et al.* (2011) described the widespread invasive form as *Deroceras invadens*.

‡Forsyth (2004) applied the name *Euconulus praticola* for snails from BC that were clearly separate from *Euconulus fulvus* in shell morphology and habitat. Subsequent work by Horsáková *et al.* (2019) supported the existence of a cryptic species within *Euconulus alderi* (Clade G in their analysis) in southeast BC, which corresponds to this taxon.

(29%), *H. camelus* (27%), Spruce Snail (*Microphysula ingersollii*, 27%), Idaho Forestsnail (*Allogona ptychophora*, 19%), and Western Glass-snail (*Vitrina pellucida*, 18%). Four species, *A. kochi occidentalis*, *C. mullani*, *K. burkei*, and Reticulate Taildropper (*Prophysaon andersonii*), were found predominantly in the ICH zone, while others showed no obvious affinities with specific biogeographic zones. Species common in coastal forests and with vicarious or potentially vicarious coastal–inland distributions included Pacific Banana Slug (*Ariolimax columbianus*), Robust Lancetooth (*Haplotrema vancouverense*), Western Flatwhorl (*Planogyra clappi*), Conical Spot (*Punctum randolphii*), Northwest Striate (*Striatura pugetensis*), and Northwest Hesperian (*Vespericola columbianus*); all were encountered at only a small number of sites (Table 1).

Of the focal species, *M. mycophaga* was detected infrequently at widely spaced sites, all except one of which (Mount Revelstoke) represented new localities for the species (Figure 2); the previous record from Mount Revelstoke, a specimen collected in 1937 by K. Racey, was discovered in February 2014 by one of us (K.O.) during examination of unidentified gastropod specimens catalogued in the RBCM collection. *Hemphillia camelus* was widespread within the study area and the most commonly encountered slug. We detected no obvious morphological differences among individuals or sites that would suggest the presence of more than one species; reproductive anatomy of a small number of dissected specimens (n = 3) conformed with this species. *Anguispira kochi occidentalis*, *C. mullani*, and *K. burkei* were detected mainly in the western portion of the study area. Records for *Z. idahoensis* were confined to a relatively small area in the south within ~25 km of the Canada–USA border (Figure 2), while the other species were more widespread. In contrast, *Oreohelix* species were found mainly toward the Rocky Mountains in the eastern portion of the study area, where they appeared to be exceedingly abundant at many sites. We identified most of the specimens as Rocky Mountainsnail (*Oreohelix strigosa*) based on shell morphology, but there was much variability in shell shape and size both within and among sites. Snails in subalpine habitats with a relatively high spire were identified as Subalpine Mountainsnail (*Oreohelix subrudis*). As noted by Forsyth (2004), taxa referred to as *O. strigosa* and *C. mullani* in BC may in fact each consist of species complexes that may include as yet unidentified species, as also appears to be the case on the USA side of the border to the south (Burke 2013). Selected species detected during the surveys are featured in Figure 3.

Discussion

Terrestrial gastropods detected during the surveys represent several faunal elements including widespread species, some with holarctic distributions, regional endemics to the Columbia basin and surrounding mountains, those with vicarious distributions with a coastal and interior component, and introduced species of Eurasian origin. Examples of widespread native species include Meadow Slug (*Deroceras laeve*), *D. whitneyi*, *E. fulvus*, *M. ingersollii*, and Quick Gloss (*Zonitoides arboreus*). Regionally endemic species previously reported from the region include *A. kochi occidentalis*, *C. mullani*, *H. camelus*, *O. strigosa*, and *O. subrudis*.

In addition to providing numerous new records for the regionally endemic focal species, the surveys resulted in the documentation of two species of slugs new to Canada, *K. burkei* and *Z. idahoensis*. Both species were subsequently determined to be of conservation concern in Canada (COSEWIC 2016a,b). *Kootenaia burkei* was described only recently from specimens from Idaho (Leonard *et al.* 2003), and before this study it was known from the Idaho Panhandle and northwestern Montana. The known distribution of *Z. idahoensis* was similar (Burke 2013). This study revealed that a large proportion (~35%) of the global distribution of *K. burkei* is in Canada, whereas the Canadian distribution of *Z. idahoensis* appears to be much more restricted.

Other interesting observations include the detection of Fir Pinwheel (*Radiodiscus abietum*), a regional endemic, at two sites in September 2013 (Figure 4). To our knowledge, this species has been documented from Canada previously only by Nekola *et al.* (2011), who found it at five localities in New Denver, BC, and in the lowlands southward in 2011. We detected Boreal Top (*Zoogenetes harpa*), a species with a holarctic distribution, at only one site. This species is known to occur sporadically in northern BC and along the Rocky Mountains (Forsyth 2004), but appears to be rare and/or patchily distributed in the Kootenay region.

Of the species common in Pacific coastal forests and with apparently vicarious distributions, *P. clappi* and *S. pugetensis* were detected infrequently and appear to be very patchily distributed in the study area. Both species have been reported previously from a small number of sites in the Kootenay region (Nekola *et al.* 2011). Additional species with such distributions detected for the first time during the surveys were *A. columbianus* at two sites, both of which receive heavy recreational use, *H. vancouverense* at five sites, and *V. columbianus* at one site, a moist, disturbed site along the highway near the international border where the latter two species co-occurred. Whether the presence

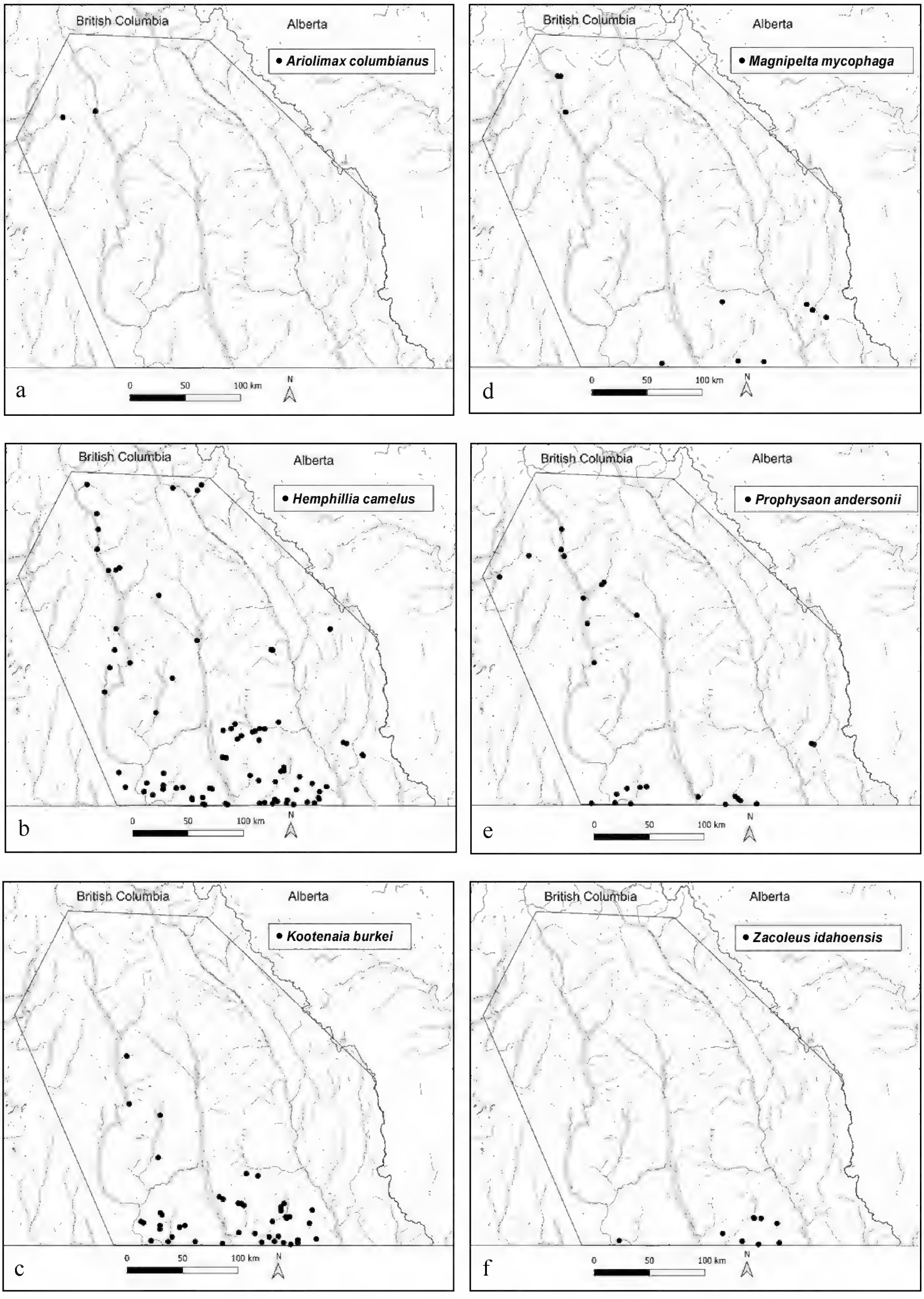
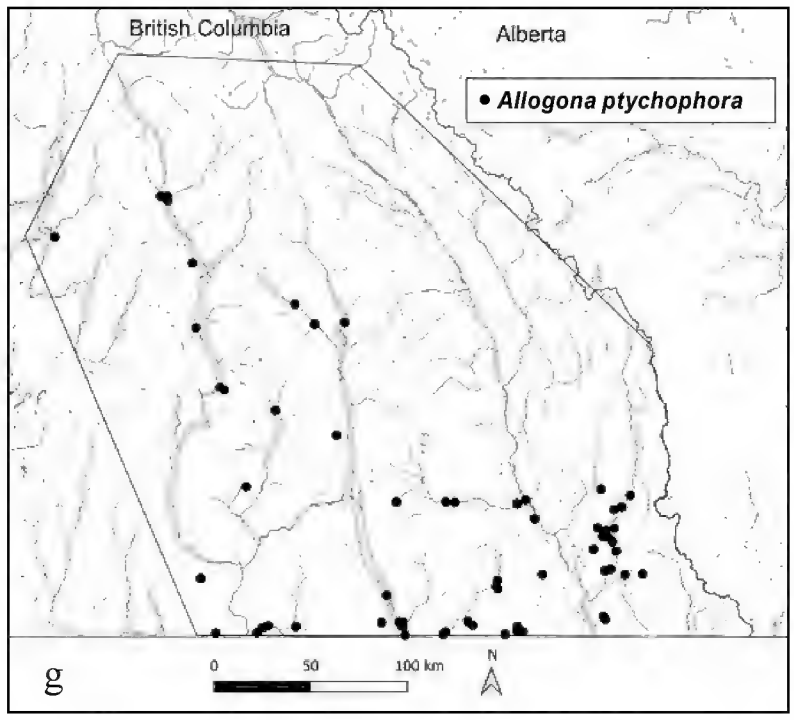
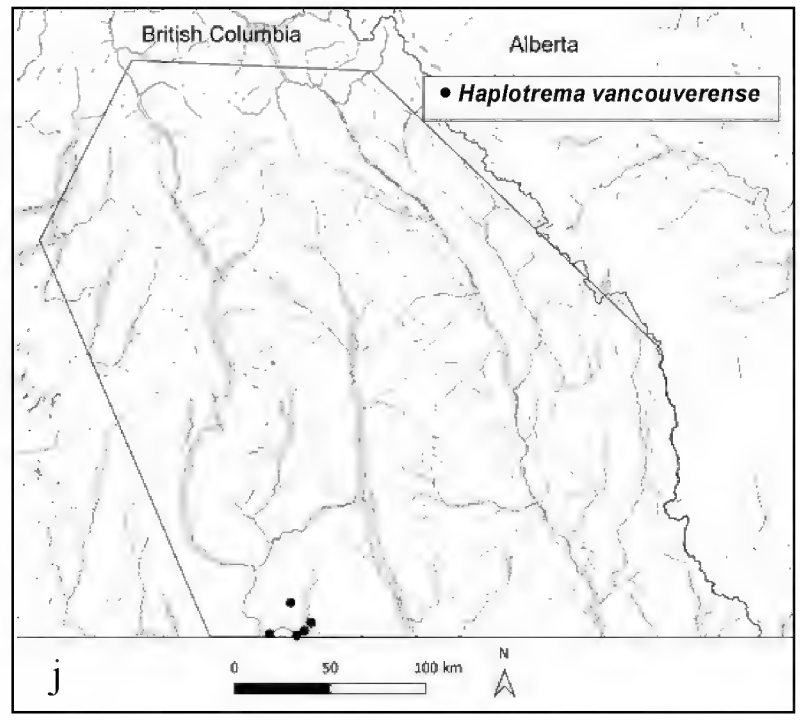
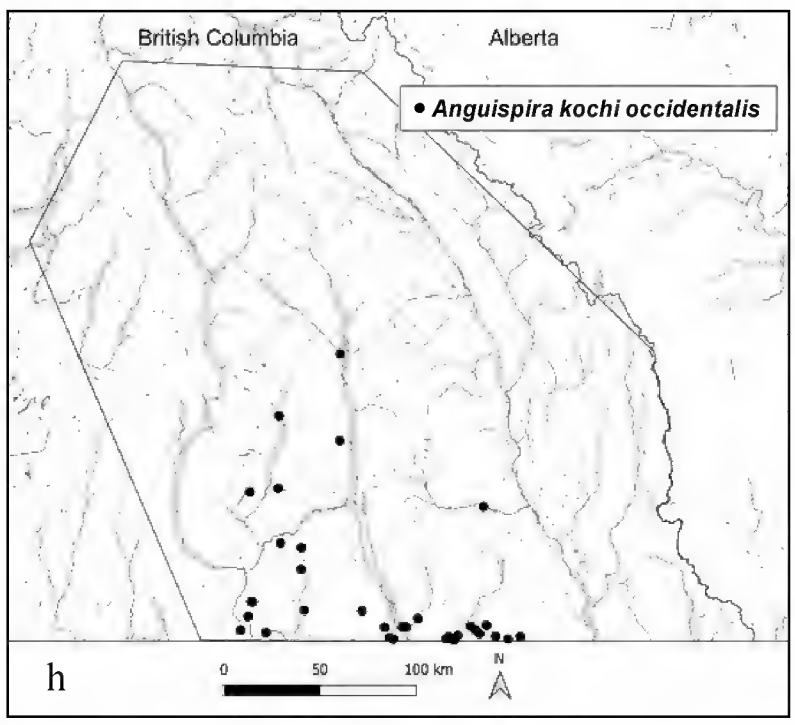
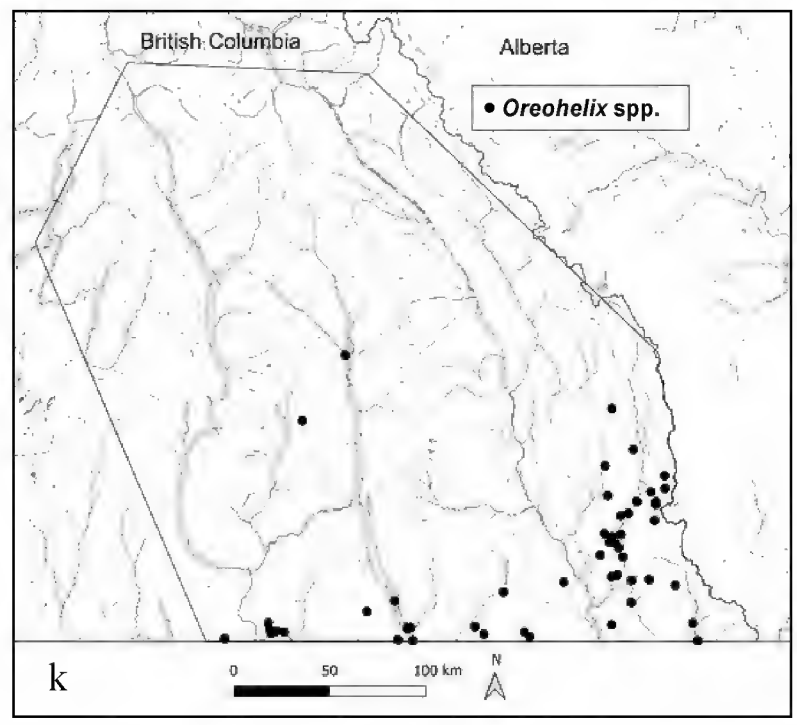


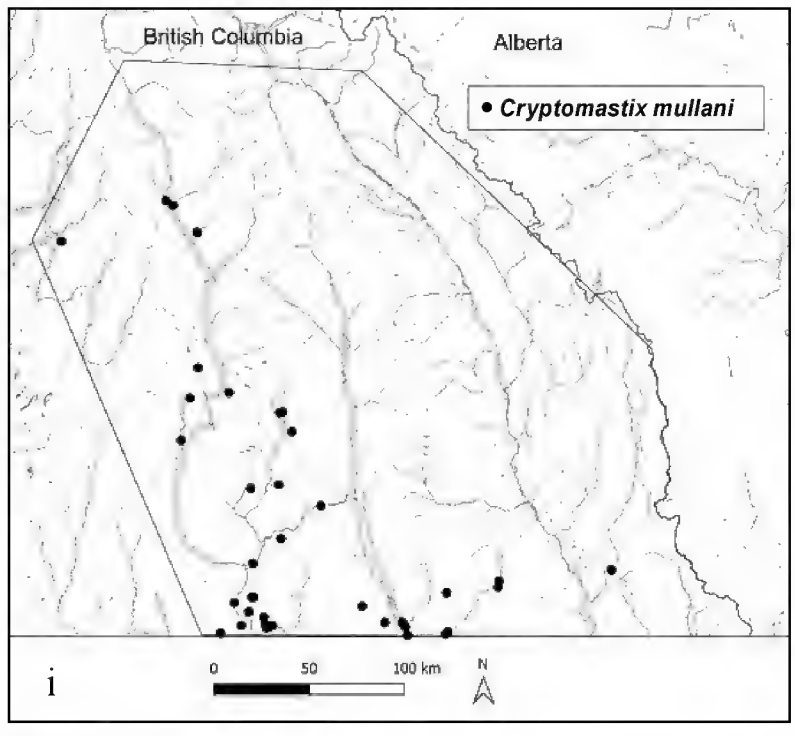
FIGURE 2. Comparison of the distributions of selected species of slugs, a–f, and large snails, g–l, detected in the study area in southeastern British Columbia.











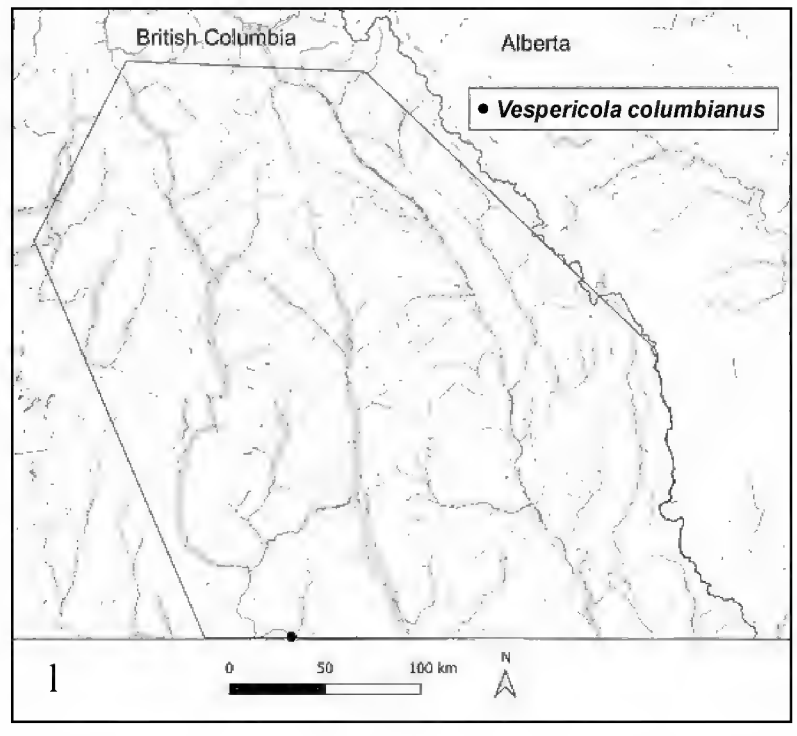


FIGURE 2. *Continued.*

FIGURE 3. Selected species detected during surveys in the Kootenay region, 2007–2015. a. Sheathed Slug, *Zacoleus idahoensis* (September 2013, site 158, 25 mm, *in situ*); b. Pygmy Slug, *Kootenaia burkei* (September 2014, site 230, 12 mm, *in situ*); c. Pale Jumping-slug, *Hemphillia camelus* (September 2014, site 83, juvenile 35 mm, *in situ*); d. Magnum Mantleslug, *Magnipelta mycophaga* (July 2007, site 267, 65 mm, *in situ*); e. Coeur d'Alene Oregonian, *Cryptomastix mullani* (September 2007, site 142, 15 mm); f. Rocky Mountainsnail, *Oreohelix strigosa* (September 2007, site 142, 20 mm); g. Western Banded Tigersnail, *Anguispira kochi occidentalis* (3 September 2008, site 78, 25 mm, *in situ*); h. Idaho Forestsnail, *Allogona ptychophora* (September 2010, site 14, 22 mm). Size is extended length for slugs, shell width for snails. Photos: Kristiina Ovaska.

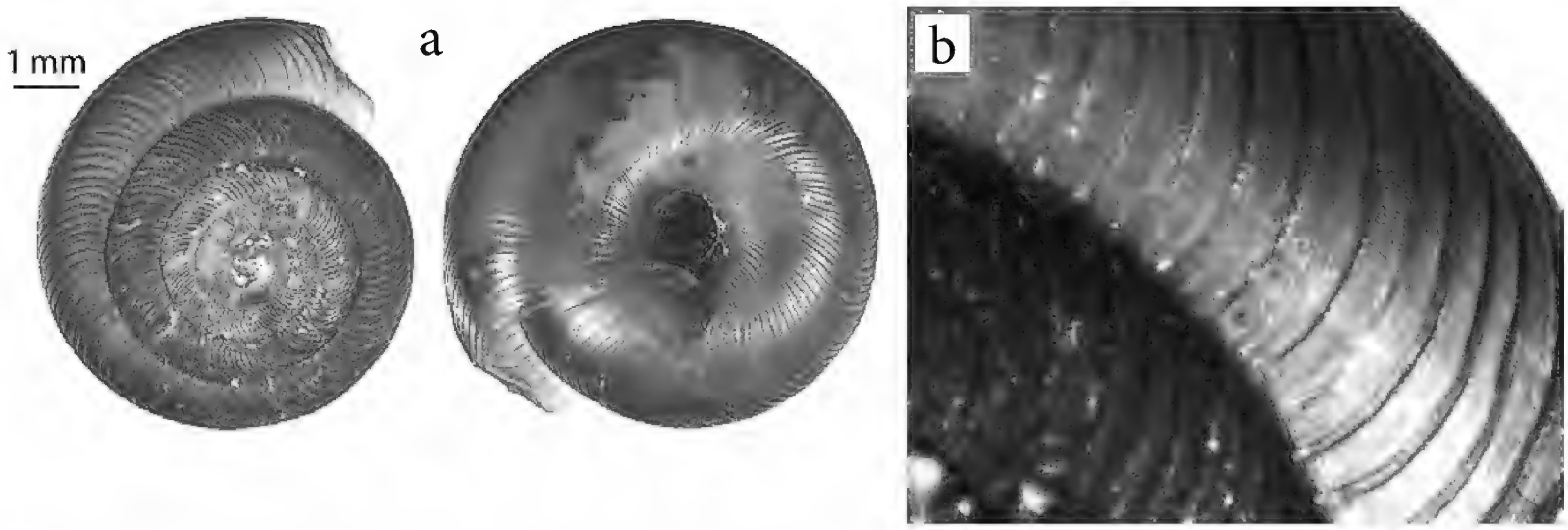


FIGURE 4. a. Fir Pinwheel, *Radiodiscus abietum* (23 September 2013, site 85) from the Kootenay region. b. Detail of shell with diagnostic fine spiral striae. Photos: Kristiina Ovaska and Heidi Gartner.

of these species represents natural distribution or resulted from recent introductions by humans from the coast remains unknown.

Non-native species encountered during the surveys include the snails Iroquois Vallonia (*Vallonia excentrica*) at one site, adjacent to hot springs at a recreational site, and Grovesnail (*Cepaea nemoralis*) at three lower elevation sites, two of them in provincial parks. Introduced slugs of three families (Agriolimacidae, Arionidae, Limacidae) were widespread within the study area and occurred at 51 sites (16.2%), distributed across all five biogeoclimatic zones sampled and often associated with human-modified habitats.

This study contributes to a growing body of information on distributions of terrestrial gastropods of southeastern BC. Most of the sampling sites were in the ICH biogeoclimatic zone, which was expected to provide suitable habitat for most of the focal species. Higher elevation sites in the ESSR and MS zones, in particular, merit further surveys, but pose logistic challenges because of difficulties of access. Yet, these habitats may contain unique species and faunas that might be particularly vulnerable to climate change impacts, as reported in other areas (Müller *et al.* 2009).

Author Contributions

Writing – Original draft: K.O. and L.S.; Writing – Review & editing: K.O., L.S., and J.H.; Conceptualization: K.O., L.S., and J.H.; Surveys & specimen identification: K.O. and L.S.; Logistics & landowner contacts: J.H.; Funding acquisition: J.H.

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SUPPLEMENTARY MATERIAL:

Appendix S1. List of sites surveyed for terrestrial gastropods in the Kootenay region, British Columbia, 2007–2015.

Appendix S2. List of voucher specimens deposited to collections at Royal British Columbia Museum, Victoria, British Columbia.

The Canadian Field-Naturalist

Conspecific cues encourage Barn Swallow (*Hirundo rustica erythrogaster*) prospecting, but not nesting, at new nesting structures

Andrew J. Campomizzi[1,*], Zoé M. Lebrun-Southcott[1], and Kristyn Richardson[2]

[1]Bird Ecology and Conservation Ontario, 114 Vaughan Road, Suite 307, Toronto, Ontario M6C 2M1 Canada
[2]Bird Studies Canada, P.O. Box 160, 115 Front Street, Port Rowan, Ontario N0E 1M0 Canada
[*]Corresponding author: andy@beco-birds.org

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Abstract

Shed-like structures are being built to provide Barn Swallow (*Hirundo rustica erythrogaster*) nesting habitat in response to population declines. However, Barn Swallow use of these structures is unavailable in the literature. We conducted three manipulative experiments to test if adding conspecific cues (i.e., vocalizations and decoys) to newly-built structures affected prospecting visits by Barn Swallows (1) during pre-breeding, (2) during post-breeding, and (3) during or after broadcasts of vocalizations compared to before broadcasts. Additionally, we monitored nesting following pre- and post-breeding cues. We built one nesting structure with and one without conspecific cues at each of 10 study sites in southern Ontario, Canada where nesting habitat was recently lost. We detected about twice as many Barn Swallows immediately after conspecific broadcasts compared to before. We did not find substantial differences in abundance and interactions with new nesting structures for other comparisons involving conspecific cues. Following pre-breeding cues at 10 sites, six nests were built in three of 10 structures treated with conspecific cues, compared to five nests in four of 10 structures without cues. In the subsequent breeding season following post-breeding cues at eight sites, four nests were built in two of eight structures treated with conspecific cues, compared to four nests in three of eight structures without cues. Conspecific vocalizations appeared to increase prospecting behaviour, but not the number of nests, at new nesting structures. The paucity of nests on new structures suggests that building shed-like structures may not be an effective method of mitigating loss of nesting habitat.

Key words: Aerial insectivore; conspecific attraction; habitat restoration; nesting habitat; Ontario; prospecting; public information; social cues

Introduction

Social cues provide inadvertent information from an animal engaged in its activities and convey information about a species' habitat that can be observed by other animals (Danchin *et al.* 2004). There is empirical evidence that territorial and colonial-nesting migratory birds can be attracted to nesting areas by experiments that introduce conspecific cues (e.g., Ahlering and Faaborg 2006; Hahn and Silverman 2006; Farrell *et al.* 2012). Thus, conspecific cues have potential application in conservation of various species to attract nesting birds to restored or protected habitat.

Previous research has shown that migratory songbirds can be attracted with conspecific cues to locations that do not provide typical conditions of a species' breeding habitat (Nocera *et al.* 2006). Such circumstances could produce an ecological trap, in which individuals identify a location as breeding habitat because of artificial conspecific cues, but the location negatively affects breeding (Schlaepfer *et al.* 2002). Alternatively, if conspecific cues increase the size of a breeding colony, there may be increases in reproductive success through various mechanisms such as predator dilution, group vigilance, or extra-pair paternity (Parrish and Edelstein-Keshet 1999; Danchin *et al.* 2000). Prospecting behaviour to visit potential nesting areas can occur before, during, or after the breeding season for adults and late in the breeding season for hatch-year birds, after they are independent from parents (Reed *et al.* 1999; Doligez *et al.* 2004; Ward 2005).

Conspecific cues could potentially aid conservation of Barn Swallow (*Hirundo rustica erythrogaster*), an aerial insectivore. Populations of birds that forage on flying insects while in flight have declined markedly over the last several decades in North America (Nebel *et al.* 2010; Sauer *et al.* 2013, 2017; Smith *et al.* 2015), leading to conservation concern and recovery efforts. These aerial insectivores include species from four taxonomic families:

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nighthawks and nightjars (Caprimulgidae), swifts (Apodidae), tyrant flycatchers (Tyrannidae), and swallows (Hirundinidae). Barn Swallow is the most abundant and widespread swallow species worldwide (Brown and Brown 1999) and considered least concern by the International Union for Conservation of Nature (BirdLife International 2016). Although still common in many rural areas, the Barn Swallow population declined by 80% in Canada and 66% in Ontario between 1970 and 2012 (Heagy *et al.* 2014), leading to its listing as threatened by the governments of Canada (Government of Canada 2017) and Ontario (MECP 2012). The reasons for its population decline are not well understood, but potential causes include: (1) loss of nesting habitat; (2) loss or degradation of foraging habitat impacting prey insects; (3) climate change and mortality from extreme cold weather events on breeding grounds; (4) pollution and pesticides; (5) reduced fecundity because of predation, ectoparasites, and persecution by humans; and (6) loss of, and human disturbance at, roosts (COSEWIC 2011; Heagy *et al.* 2014).

In Ontario, Barn Swallows breed predominantly south of the Canadian Shield in the Mixedwood Plains ecozone (Lepage 2007). They breed in various non-forested areas and are typically associated with human-built structures that provide nesting opportunities, such as barns, bridges, and sheds (Brown and Brown 1999). Recently, structures specifically designed as Barn Swallow nesting habitat have been built. In Ontario, most nesting structures are built as mitigation for habitat loss as required by the Ontario Ministry of Environment, Conservation and Parks (e.g., due to building or bridge demolition or renovation; MECP 2013); others are built to provide new nesting habitat. There are reports providing information about nesting in these structures (e.g., Heagy *et al.* 2014; K.R. unpubl. data), but we were unable to find information in the literature. Overall, the frequency of use of these structures for nesting by Barn Swallows is unclear because few results are available. Although loss of nesting habitat is only one potential factor contributing to Barn Swallow population declines, it is important for conservation efforts that address habitat loss to make the best use of funds and opportunities by providing nesting habitat that is most likely to be used productively by the species.

Barn Swallows often nest colonially (Brown and Brown 1999), suggesting they may use conspecific cues (e.g., the presence of adults at a nesting structure) when selecting nest sites. There is some evidence of success in using conspecific cues to attract Purple Martin (*Progne subis*; another swallow species) to nest in previously unoccupied martin houses (Kostka 2000). We hypothesized that introducing conspecific cues (i.e., decoys and vocalizations), to make it appear that a structure was already being used by nesting Barn Swallows, would increase the likelihood of nesting at a new structure.

There is evidence that the presence of old nests influences the use of a nest site by Barn Swallows. Safran (2004) found that removing old nests before birds arrived on the breeding grounds reduced the proportion of immigrant female Barn Swallows at sites in New York. Additionally, birds that reused old nests had higher seasonal fecundity than those that built new nests (Safran 2004). Settlement patterns of females breeding at a site for the first time were associated with the number of old nests, rather than the prevalence of colourful males or opportunities for extra-pair copulations (Safran 2007). Ringhofer and Hasegawa (2014) found that the number of old undamaged nests was associated with the spring arrival date of male Barn Swallows at nest sites. Thus, both conspecific cues and the presence of old nests likely influence the use of nest sites by Barn Swallows.

Barn Swallows likely gather information about numerous potential nest sites before selecting one for breeding, as occurs with other migratory songbirds (Brown and Brown 1999; Reed *et al.* 1999). Visits to nesting structures by Barn Swallows likely indicate that individuals are gathering information about the structure for potential future use for nesting. Attracting Barn Swallows to new nesting structures could positively or negatively influence reproductive success. Breeding success of Barn Swallows can decrease with increasing number of proximate nests (Shields and Crook 1987); however, it is unknown how the use of conspecific cues might influence the reproductive success of the species.

Our goal was to test the influence of conspecific cues on the use of newly built nesting structures by Barn Swallows to inform conservation efforts that include the creation of nesting structures. In experiment one, we monitored pre-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues (i.e., vocalizations and decoys) more frequently than structures without cues. In experiment two, we monitored post-breeding prospecting visits to assess if birds visited structures with conspecific cues more frequently than structures without cues. In experiment three, we further investigated the immediate response to conspecific vocalizations by assessing if Barn Swallows visited structures more frequently during or after vocalization broadcasts compared to before broadcasts. Additionally, we monitored nesting following pre- and post-breeding cues to assess if conspecific cues influenced the number and success of Barn Swallow nests at nesting structures.

Study Area

We located study sites where an old structure with nesting Barn Swallows was removed or made unavailable to the birds. This situation enabled us to simulate the circumstances under which many new nesting structures are being built in Ontario (i.e., mitigation for loss of nesting habitat under the *Endangered Species Act* [MECP 2013]). We coordinated the construction of two new nesting structures at each site, during the fall or spring, prior to the breeding season. The result was a paired design, with two new nesting structures on each study site, one treatment with conspecific cues and one control without conspecific cues, thus allowing us to assess the influence of the cues on Barn Swallow use of the new nesting structures. We flipped a coin to randomly select one of the two structures on each of the 10 study sites to have conspecific cues (i.e., decoys and a broadcast box).

We established 10 study sites in southern Ontario between Erin (43.766°N, 80.058°W) in the north and Port Rowan (42.626°N, 80.452°W) in the south. We opportunistically identified study sites through existing contacts and by directly contacting landowners. Barn Swallow nesting habitat was lost at study sites prior to our study because structures were demolished or access to structures was blocked due to building renovation, nesting deterrents, or a need to keep doors closed (Table 1). The number of Barn Swallow nests in structures where habitat was lost varied, from one to ~50, across study sites (Table 1). We were unable to estimate the number of nests that were used in the year before habitat was lost, which would have provided better information about the number of nesting pairs compared to the number of nests. To the best of our knowledge, Barn Swallows nested at ≥8 of the 10 study sites in the year prior to our experiment.

We used the following criteria to guide where to place new nesting structures. We placed structures in non-forested areas with foraging habitat for Barn Swallows (i.e., grassland, cropland; Brown and Brown 1999). Additionally, we attempted to build new structures ≤1 km from the previous nesting location to meet mitigation guidelines (MECP 2013) and so that Barn Swallows returning to the site could easily encounter the new structures. We attempted to place the two new structures equal distances from the location of the demolished, renovated, or closed structure and about 400 m apart from each other to minimize the effects of the conspecific cues on the control structure (i.e., to ensure that broadcasted vocalizations were inaudible at control structures). Additionally, we attempted to place structures >100 m from forest edges to maximize availability of proximate foraging habitat. Because of constraints on study sites, we placed nesting structures 81–1220 m (mean = 427 m) from the location where Barn Swallows nested previously, 265–589 m (mean = 378 m) apart from each other, and 16–474 m (mean = 167 m) from the nearest forest edge based on land cover data from the Southern Ontario Land Resource Information System (MNRF 2000).

Methods

Structures

We designed nesting structures using the best available information about what Barn Swallows would most likely use (Brown and Brown 1999). However, information about structures built for Barn Swallow nesting is limited and not in the literature. The best available information suggested building

TABLE 1. Reason for habitat loss, number of Barn Swallow (*Hirundo rustica erythrogaster*) nests in lost habitat in year before monitoring (number of previously-active nests unknown), number of new nests in structures with and without pre-breeding conspecific cues built to replace lost habitat, and the year each study site was monitored.

Site	Old structure		No. nests in new structure		Year monitored
	Habitat lost	No. nests	Conspecific cues	No cues	
AN	Barn demolished	~12	2	2	2014
CH	Barn access denied	Unknown*	0	0	2015
DA	Barn access denied	1 to 2†	0	0	2015
DR	Barn access denied	~6 pairs‡	0	0	2015
GU	Barn access denied	1§	0	0	2015
LA	Barn demolished	6	0	1	2014
LE	Barn demolished	20 to 50	2	1	2015
RA	Eaves access denied	1	2	0	2015
WA	Barn access denied	4 to 5	0	1	2015
WI	3 buildings demolished	~15	0	0	2015

*Landowner observed several nesting pairs previously using structure, but structure was inaccessible to confirm presence of nests.
†Nests active in 2012.
‡Number of nests unknown, landowner estimated six nesting pairs.
§Unknown if nest active in 2014.

structures with similar characteristics to bridges and barns that are used for nesting, including rough vertical surfaces on which birds can build nests, shelter from wind and rain, visual barriers between nests, and a structure large enough to support several nesting pairs (MECP 2013; L. Sarris pers. comm. 13 February 2014; K.R. unpubl. data). We designed a wooden structure with a metal roof, 4.9 m long, 1.3 m wide at the nesting compartments, and 3.7 m tall at the peak of the roof (Figure 1). The structure included 16 nesting compartments, two rows of eight compartments along the 4.9-m length of the structure. In each row of eight compartments, we alternated available nest supports by providing a wooden nest cup (i.e., a wooden replica of a nest) in one compartment and bridging in the shape of the letter X, as found in some old barns, in the next compartment. Each compartment was bordered by 5 × 25 cm lumber along the center and along the outside of the structure and 5 × 15 cm lumber between compartments on the inside of the structure to provide a visual barrier between nests. Compartments had a flat ceiling above and no obstructions below. To provide shelter from weather, we added 40 cm of lumber along the outside of the structure below the nesting compartments.

FIGURE 1. One of the nesting structures built to test the impact of conspecific cues on prospecting and nesting by Barn Swallows (*Hirundo rustica erythrogaster*) in southern Ontario, Canada. Photo: A.J. Campomizzi.

Each structure was equipped with nest cups, perches, and predator deterrents to encourage use by Barn Swallows and decrease risk of nest predation. We placed nest cups on all structures because they are required for mitigation projects in Ontario (MECP 2013). Although the presence of old nests may increase the chance of nesting, Barn Swallow response to nest cups is unknown. We placed 16 nest cups on each structure, eight on the inside and eight on the outside of the structure. We placed nest cups far enough from ceilings (6.4 cm) and roofs (6.4 cm under roof peaks and 10.8 cm under sloped roofs) to allow the birds to build a mud rim along the top of the cup. The distance between the top of the nest cup and the ceiling or roof above was based on instructions provided by a nest cup supplier (American Artifacts, Taneytown, USA) and Barn Swallow nest placement (i.e., typically 2.5 to 6.0 cm from a ceiling; Brown and Brown 1999). We attached four perches to each structure; two on the inside and two on the outside. We included perches on the structures because there is evidence that adults lead juveniles from the nest to a perch, fledglings frequently perch after leaving the nest, and fledglings are initially fed by parents while perched (Brown and Brown 1999). To deter mammalian nest predators from accessing and preying on nests, we covered each support post with galvanized sheet metal (Figure 1).

Experiment one: pre-breeding prospecting

We monitored structures at 10 study sites (two sites in 2014 and eight in 2015). We placed seven carved Barn Swallow decoys (Olde World Carvings, Spartanburg, South Carolinia, USA; Starr Decoys, Weybridge, Vermont, USA) at each treatment structure on perches and nests to make it appear as though the structure was being used, but not fully occupied, by nesting Barn Swallows.

We attached the broadcast box to a small shelf about 1.5 m from the ground on a post that supported each treatment structure. We largely followed Farrell and Campomizzi (2011) for the design of the broadcast box, resulting in a plastic box containing a compact disc player, amplified speaker, battery, and timer that broadcasted Barn Swallow vocalizations periodically throughout the day. We made a 30-min audio track of Barn Swallow songs, non-alarm calls, and periods of silence to simulate an active Barn Swallow nesting colony. To assemble the 30-min track, we obtained eight audio recordings made in Ontario and adjacent US states from the Cornell Lab of Ornithology (2014). To provide vocalizations throughout the day, we programmed the timer to turn the broadcast box on for 30 min at 0600, 0700, 0800, 1000, 1200, 1500, 1700, and 1900. We used the literature about Barn Swallow vocalizations to guide our selection of songs

and calls to include, when to broadcast the vocalizations during the day, and the number of vocalizations interspersed with silence (Samuel 1971; Brown 1985; Brown and Brown 1999). We installed conspecific cues for the return of Barn Swallows to the study area for breeding in the spring. We continued broadcasting vocalizations for the duration of the nesting season, until late August in 2014 and early September in 2015.

Across 2014 and 2015, we monitored 10 treatment and 10 control structures for pre-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues more frequently than structures without cues and to record their behaviour. We conducted prospecting surveys at a designated survey location 50 m from each structure twice per week, between sunrise and sunset. Pre-breeding prospecting surveys occurred from 24 April to 14 June. This period corresponds to Barn Swallow arrival in the study area and the beginning of nesting. Seven to 21 days pass between pair formation and egg laying (Brown and Brown 1999) and the earliest egg date for Ontario is 10 May (Peck and James 1987).

During each 10-min survey, we recorded each Barn Swallow detected within 50 horizontal m of the structure. During each 2-min interval of the 10-min survey, we recorded each individual detected, its distance from the structure, if it behaviourally interacted with the structure (perched on, flew under, or flew into or out of the structure). We also recorded if we detected an individual carrying nest material during the 10-min survey and if birds interacted with, perched next to, or attempted to copulate with decoys. We recorded a conservative estimate of the number of individuals to avoid counting one individual multiple times during a survey. We conducted surveys during weather conducive to Barn Swallow activity and detection (i.e., not during rain or strong wind). We noted if nest predators were on or attempting to get on the structure. After each survey, we walked to the structure to see if birds were inside and to monitor nests, as described below.

Experiment two: post-breeding prospecting

Following the pre-breeding prospecting experiment at each study site, we monitored 10 treatment and 10 control structures for post-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues more frequently than structures without cues, and to record their behaviour. Using the same broadcast schedule of Barn Swallow vocalizations and bird survey methods described above, we conducted post-breeding surveys from 20 July to 5 September, a range that includes when pairs not attempting second broods are finishing caring for dependent fledglings to when we no longer saw birds in breeding areas. The latest egg date for Ontario is 21 August (Peck and James 1987).

Experiment three: prospecting before, during, and after

In 2016, we placed conspecific vocal cues at three structures that were randomly selected as treatments in 2015 but were not used for nesting by Barn Swallows in 2015. In 2016, each of the three study sites had a pair of structures, one with and one without conspecific vocal cues. We did not use decoys for experiment three.

We changed the frequency and duration of vocalizations played on each day at each treatment structure compared to 2015 to enable assessment of Barn Swallow visits before, during, and after broadcasts of vocalizations. Vocalizations played for 20 min at the start of each hour between 0600 and 2100. Broadcasts began on 19 April and ceased on 6 June.

In 2016, we surveyed the three nesting structures for pre-breeding prospecting visits by Barn Swallows. We designed surveys to document Barn Swallows searching for nest sites (particularly behavioural interactions with structures) and if conspecific cues influenced the frequency of detections. We visited treatment structures twice per week, once in the morning and once in the afternoon or evening, for a one hour survey. We scheduled the majority of surveys during the morning and evening because, in 2014 and 2015, we observed more Barn Swallow activity during these times compared to other times. The survey hour consisted of 20 min before the broadcast, 20 min of broadcast, and 20 min after the broadcast. We observed treatment structures from a designated survey location 50 m away, recording all individual Barn Swallows that came within 50 horizontal m. Survey periods were broken into 5-min intervals to record possible variation in bird abundance and behaviour throughout the survey. During each 5-min interval, we recorded detections of each individual. For each Barn Swallow detected, we recorded its horizontal distance from, and interactions with, the nesting structure. We conducted surveys during weather conducive to Barn Swallow activity and detection.

After each survey, we approached the treatment structure to look for signs of nesting and check active nests. We did not conduct prospecting surveys of the control structures on the three study sites because we were testing Barn Swallow response to broadcasts at treatment structures only (prospecting surveys at control structures were conducted for the pre-breeding and post-breeding prospecting experiments, see above). We checked for nesting activity at control structures after surveys were completed at treatment structures.

Nest monitoring

We monitored nests to assess differences in the number of nests and nest success of Barn Swallows

between structures with and without conspecific cues. We monitored 10 study sites across 2014 and 2015 following pre-breeding conspecific cues. Additionally, we monitored nesting at eight study sites in 2016 following post-breeding conspecific cues applied in 2015. Nest monitoring occurred from 12 May to 22 August. We followed nest monitoring protocols for Barn Swallows provided on Bird Studies Canada's Project NestWatch website (http://www.birdscanada.org/volunteer/pnw/index.jsp?targetpg=barsmonitor), with minor modifications. We looked for evidence of nest building while conducting bird surveys early in the breeding season. At the five study sites without bird surveys in 2016, the frequency of nest monitoring visits varied based on whether there were active nests at the site. We checked active nests approximately once per week until nesting activity ceased. Sites without active nests were checked periodically throughout the season.

We began monitoring nests with a mirror to observe nest contents on the visit after a nest appeared fully built, to minimize the chance of nest abandonment. We checked nest contents with a mirror once every five to seven days. During each nest check, we recorded the number of eggs, number and age of young, brood parasitism, adult activity, and condition of the nest. We did not check nest contents with a mirror if nestlings were >10 days old, to avoid potentially causing young to fledge prematurely; instead, we observed the nest from a distance with binoculars. We continued to check nesting structures for active nests throughout the breeding season.

Analyses

We did not use statistical analyses for nest data because sample size of nests was too small. Instead, we described nesting activity. For bird survey data, we first explored data through graphs and descriptive statistics. We excluded survey data collected while Barn Swallow nests were active at a structure to ensure that detections were of prospecting birds, not adults attending to nests. We used means and CI to assess the direction, magnitude, and precision of effects (Johnson 1999; Wasserstein and Lazar 2016), and interpreted their biological importance (Guthery *et al.* 2001; Nakagawa and Cuthill 2007; Nuzzo 2014). We calculated means and CI for the difference in Barn Swallow detections and interactions with structures from spatially and temporally paired surveys described below. We conducted analyses using R (version 3.4.1, R Core Team 2017).

Experiment one: pre-breeding prospecting: We separately compared the abundance of Barn Swallows detected and interacting with structures during pre-breeding surveys. We compared the difference in abundance of Barn Swallows detected between (1) broadcast and non-broadcast times at treatments, (2) broadcast and non-broadcast times at controls, and (3) all surveys at treatments compared to controls. We made the same three comparisons in the difference in the abundance of Barn Swallows interacting with structures. For comparisons during broadcast and non-broadcast times at treatments and controls, we paired surveys conducted during the same week for each structure. For example, to calculate the difference in abundance between broadcast and non-broadcast times at each treatment structure for each week of surveys, we subtracted the number of Barn Swallows detected during the non-broadcast time from the number of individuals detected while conspecific vocalizations were broadcasted. For comparisons between treatments and controls, we paired surveys conducted on the same day for each pair of treatment and control structures at each study site. These analyses resulted in three estimates of the difference in abundance of Barn Swallows detected at structures (Figure 2a) and another three estimates of the difference in abundance of individuals interacting with structures (Figure 2b) during pre-breeding surveys. Estimated means greater than zero indicate more Barn Swallows detected or interacting with structures during broadcast compared to non-broadcast or treatment compared to control.

Experiment two: post-breeding prospecting: For post-breeding surveys, we made the same comparisons as pre-breeding surveys with one exception. We used surveys at treatments during broadcast and controls during non-broadcast only because mean abundance at treatments was more than twice as high during broadcast compared to non-broadcast times, suggesting a potential numerical response by the birds. These analyses resulted in an additional three estimates of the difference in abundance of Barn Swallows detected at structures (Figure 2a) and three estimates of the difference in abundance of individuals interacting with structures (Figure 2b) during post-breeding surveys.

Experiment three: prospecting before, during, and after: We compared the difference in abundance of Barn Swallows detected at treatment structures during broadcast versus before broadcast and after broadcast versus before. We paired data for surveys conducted on the same day for each structure. We were unable to make comparisons of the abundance of Barn Swallows interacting with structures because we did not detect interactions during these surveys. These analyses resulted in two estimates of the difference in abundance of Barn Swallows detected at structures (Figure 3). Estimated means greater than zero indicate more Barn Swallows detected during broadcast compared to before broadcast or after broadcast compared to before.

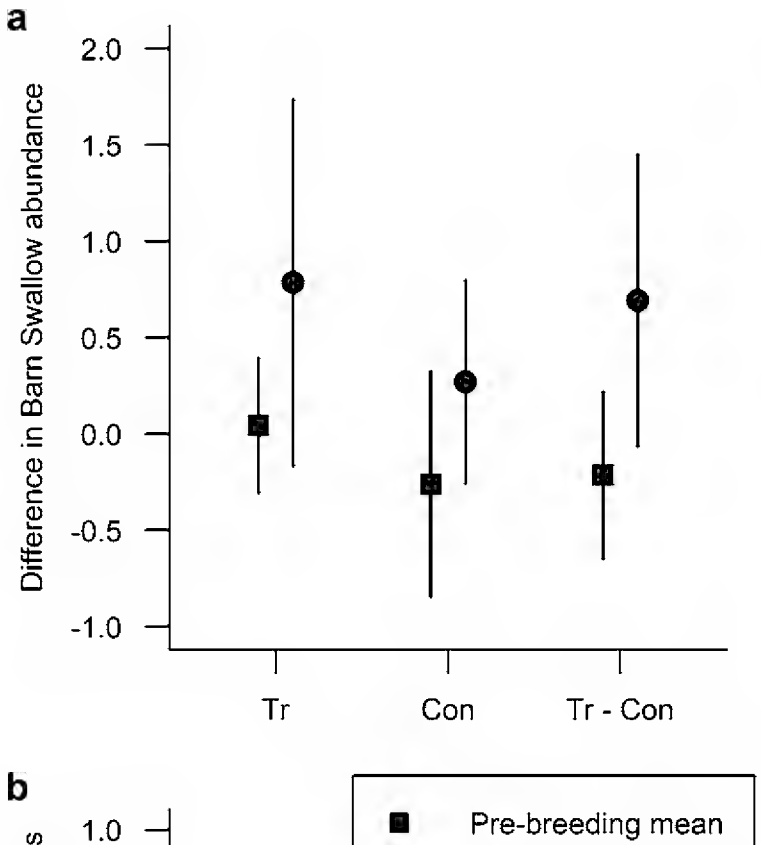

FIGURE 2. Mean and 95% CI of the difference in abundance of Barn Swallows (*Hirundo rustica erythrogaster*) a. detected and b. interacting with nesting structures (i.e., perched on, flew under, or flew into or out of the structure) with and without conspecific cues in southern Ontario, Canada in 2014 and 2015. Comparisons during pre-breeding are for structures treated with conspecific cues during broadcast minus non-broadcast surveys (Tr), control structures during broadcast minus non-broadcast surveys (Con), and all treatment minus control surveys (Tr - Con). Comparisons during post-breeding are the same for Tr and Con; the third comparison is of treatment during broadcast minus control during non-broadcast surveys only (Tr - Con).

Results

Across all surveys in 2014 and 2015, we detected Barn Swallows on 33% (n = 263) of surveys at structures with conspecific cues and 38% (n = 263) of surveys at structures without cues. Across

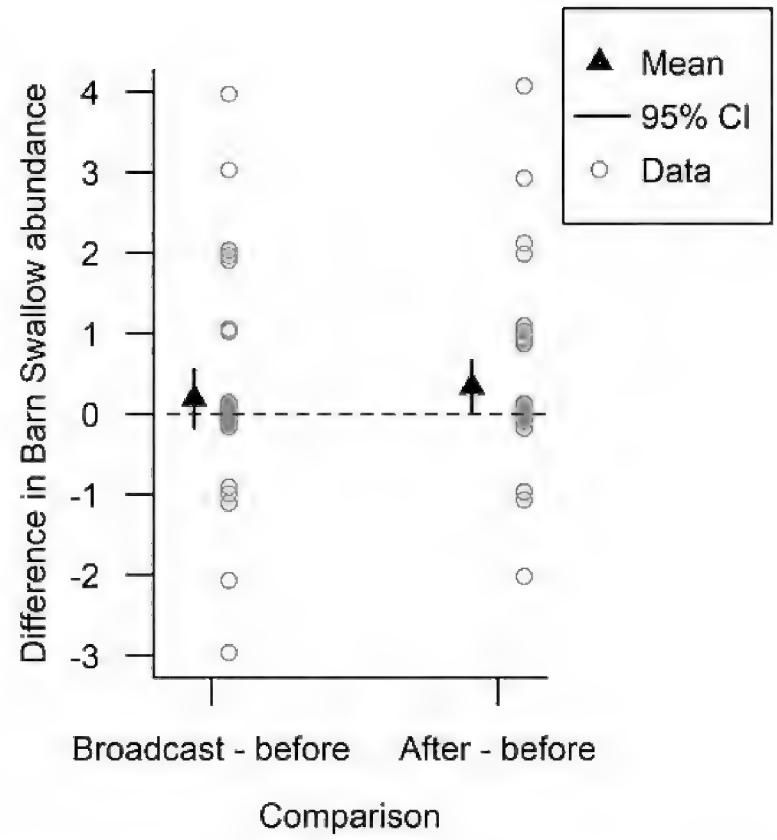

FIGURE 3. Mean, 95% CI, and observed data of the difference in abundance of Barn Swallows (*Hirundo rustica erythrogaster*) detected on one hour surveys conducted for 20 min before, during, and after conspecific vocalizations at three nesting structures in southern Ontario, Canada in 2016.

surveys with Barn Swallow detections, we detected 279 Barn Swallows on 88 surveys at structures with conspecific cues and 299 Barn Swallows on 99 surveys at structures without cues. These results include data from surveys of structures with active nests. As noted above, we reduced the dataset for the comparisons below.

Experiment one: pre-breeding prospecting

During pre-breeding, the mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times at treatments was 0.04 (n = 46) and not substantially different from zero (Figure 2a). Similarly, the mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times at controls (−0.26, n = 50) and at treatments compared to controls (−0.21, n = 98) was not substantially different from zero (Figure 2a).

Experiment two: post-breeding prospecting

During post-breeding, all three mean differences in Barn Swallow abundance were larger than during pre-breeding and greater than zero. The mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times was 0.78 (n = 42) at treatments, 0.27 (n = 48) at controls, and 0.69 (n = 52) at treatments compared to controls. These differences suggest an effect of ~0.5 individuals per survey, but 95% CI included zero, although marginally for treatments compared to controls (lower 95% CI: −0.06; Figure 2a).

The largest differences in abundance of Barn Swallows interacting with structures was during post-breeding. The mean difference in Barn Swallows interacting with structures during broadcast compared to non-broadcast was 0.28 ($n = 42$) at treatments and 0.21 ($n = 52$) for treatments compared to controls (Figure 2b). Both CI marginally included zero (lower 95% CI: −0.09 for treatments and −0.01 for treatments compared to controls), indicating some lack of confidence in an effect of ~0.2 individuals per survey interacting with structures (Figure 2b).

Experiment three: prospecting before, during, and after

We detected 40 individual Barn Swallows on prospecting surveys in 2016 and 45% ($n = 42$) of surveys for this experiment had Barn Swallow detections. We detected 12, 20, and 26 individuals before, during, and after conspecific broadcast, respectively. Mean difference in abundance of Barn Swallows detected at treatment structures was higher both during broadcast compared to before broadcast (0.19, $n = 42$) and after broadcast compared to before (0.33, $n = 42$; Figure 3). The CI for after broadcast compared to before was greater than zero (95% CI: 0.01, 0.65; Figure 3). We did not observe Barn Swallows behaviourally interacting with structures (i.e., perching on or flying inside of a structure) in 2016.

Nesting

Experiment one: pre-breeding prospecting: Across 2014 and 2015, there were six nests on three structures with conspecific cues and five nests on four structures without cues (Table 1). All nests observed with eggs eventually fledged young. Two additional nests were built on structures without cues; however, we never observed eggs in these nests. All three nesting pairs at structures with conspecific cues appeared to fledge a second clutch, compared to one of four pairs nesting at structures without cues. The earliest nest initiation date (i.e., first egg date) was 20 May at structures with conspecific cues and 21 May at structures without cues.

All nests were built in wooden nest cups in the interior of the structures. For all 11 nests monitored following pre-breeding cues, Barn Swallows added a mud rim to the top of the wooden nest cup, making the top of the nest look similar to a typical Barn Swallow nest.

Experiment 2: post-breeding prospecting: In 2016, four nests were built in two of eight structures treated with post-breeding conspecific cues in 2015, compared to four nests in three of eight structures without post-breeding cues in 2015. All eight nests were in nest cups in the interior of the structure and fledged young. One additional nest was initiated on the exterior of a structure but was abandoned after some addition of mud to a nest cup; we did not observe eggs in this nest. Two nests from 2015 were reused in 2016. Three of the eight nests appeared to be second clutches.

Experiment 3: prospecting before, during, and after: Barn Swallows did not nest at the three sites used for the experiment comparing prospecting before, during, and after broadcasts of vocalizations in 2016.

Discussion

To our knowledge, this is the first evaluation of Barn Swallow use of new nesting structures specifically built for the species. Our study provides some evidence to link prospecting behaviour by Barn Swallows at new nesting structures to broadcasts of conspecific vocalizations. During pre-breeding, Barn Swallow abundance was higher immediately after conspecific broadcasts compared to before broadcasts. However, we did not find substantial differences in Barn Swallow abundance and interactions with new nesting structures for other comparisons involving conspecific cues. Most importantly, Barn Swallows did not nest more frequently on structures treated with pre- or post-breeding conspecific cues; they nested on and fledged young from structures with and without cues, albeit in low numbers.

Our results provide some evidence that Barn Swallows can be attracted to at least investigate new nesting structures by introducing conspecific cues. On several occasions, we observed Barn Swallows approaching nesting structures immediately after the broadcast started, anecdotally suggesting a response to the start of the vocalizations. On a few occasions, we observed Barn Swallows interacting with decoys by perching on, singing at, and attempting to copulate with decoys. Previous research in the literature has not documented Barn Swallow prospecting behaviour in response to simulated conspecific cues at nesting sites. A study on Chimney Swift (*Chaetura pelagica*; another aerial insectivore species) showed that introducing conspecific vocalizations and decoys increased the length of time that the birds spent near new nesting towers (Finity and Nocera 2012). Additionally, conspecific cues introduced during post-breeding have been shown to influence habitat selection in the next breeding season for migratory songbirds (Nocera *et al.* 2006, Betts *et al.* 2008). In our study, however, Barn Swallows did not build more nests in 2016 at structures treated with conspecific cues during post-breeding in 2015, compared to structures without cues. Future research to explore the impacts of broadcasted conspecific vocalizations on prospecting behaviour and nesting may help in-

form future efforts to create nesting habitat for various species.

Some of the structures included in this project provided nesting habitat for Barn Swallows and all nests observed with eggs fledged young. We did not observe a difference in the number of nests built on structures with and without conspecific cues that were provided during pre-breeding or post-breeding. Although nesting structures provided opportunities for birds to nest on X-shaped bridging in addition to nest cups, all nests were built in nest cups. Nest cups may be an important feature of new nesting structures because they provide a nesting substrate and essentially a partially-built nest. The nest cups may attract Barn Swallows to new structures if they function similarly to old nests (*sensu* Safran 2004, 2007; Ringhofer and Hasegawa 2014) and enable birds to begin nesting earlier in the season because the birds do not need to build an entire nest. Re-using old nests can increase reproductive success (Safran 2007; but see Barclay 1988). Therefore, nest cups could be important for conservation because they may enable Barn Swallow pairs to raise a second brood, thus increasing fecundity. Combining conspecific cues and the presence of old nests (perhaps by providing wooden nest cups) may maximize the number of Barn Swallows that prospect at new nesting structures but may not lead to more nests at new structures.

It is possible that the structures with and without cues were not far enough apart to completely separate the effect of the conspecific cues. Although the distance Barn Swallows travel to prospect for nest sites is unknown, adults will forage up to 500 m from nesting colonies (Møller 1987), suggesting individuals encountering one structure on a study site could encounter the other structure. Future research to assess if conspecific cues at one structure can affect prospecting at multiple structures, or if prospecting is greater at structures with conspecific cues compared to structures without cues (at greater distances than we tested), may be helpful for understanding nest site selection and guiding conservation efforts. Additionally, most of our study sites had few nests in the nesting habitat that was lost. With few Barn Swallows returning to nest at these sites, there may have been few Barn Swallows within hearing distance of the vocalizations. The number of philopatric Barn Swallows may impact the magnitude of the effect of conspecific cues on prospecting birds.

We are uncertain how many nesting pairs could nest simultaneously on the structures used for our experiment. However, building a few of these new structures is unlikely to replace the lost nesting habitat provided by bridges or old barns with large nesting colonies (e.g., 50 breeding pairs). Building one nesting structure cost ~$2500 to $3500 (CAD). Regulators and land managers should consider if this expense is worth the benefit or if funds could be used in more effective ways to support Barn Swallow nesting habitat. A potential alternative is to provide incentives for landowners to repair and maintain aging barns that can provide nesting habitat for larger colonies of Barn Swallows and for more years than new structures (Heagy *et al.* 2014). It may also be beneficial for future research to investigate the relationship between colony size and characteristics of nesting structures and the surrounding landscape. Building new nesting structures may be an option for creating new Barn Swallow nesting habitat in locations with appropriate foraging habitat (i.e., grassland, cropland; Brown and Brown 1999), where no structure currently exists and there is an interest in contributing to Barn Swallow conservation. When structures are built for Barn Swallow nesting habitat, we recommend including wooden nest cups in the interior of the structure, which was the location of all nests in our experiment. However, more research is needed to assess if loss of nesting habitat is limiting the Barn Swallow population to determine if creating or maintaining nesting habitat is likely to have a positive impact on the population or if resources should be directed to addressing other threats to the species.

Our results confirm that new structures can provide nesting habitat for Barn Swallows but providing conspecific cues may not enhance this conservation strategy. The paucity of nests built on structures raises questions about the efficacy and efficiency of building new nesting structures to mitigate the loss of nesting habitat.

Author Contributions

Conceptualization: Z.M.L., A.J.C., and K.R.; Data Curation: A.J.C. and Z.M.L.; Formal Analysis: A.J.C.; Funding Acquisition: K.R., Z.M.L., and A.J.C.; Investigation: Z.M.L., A.J.C., and K.R.; Methodology: A.J.C., Z.M.L., and K.R.; Project Administration: Z.M.L., K.R., and A.J.C.; Resources: Z.M.L. and K.R.; Supervision: Z.M.L. and K.R.; Validation: A.J.C. and Z.M.L.; Visualization: A.J.C. and Z.M.L.; Writing – Original Draft: A.J.C. and Z.M.L.; Writing – Review & Editing: A.J.C., Z.M.L., and K.R.

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Seasonal movements of White-tailed Deer (*Odocoileus virginianus*) in the Rocky Mountains of British Columbia

Trevor A. Kinley

Parks Canada Agency, P.O. Box 220, Radium Hot Springs, British Columbia V0A 1M0 Canada; email: trevor.kinley@canada.ca

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Abstract

Nineteen adult female White-tailed Deer (*Odocoileus virginianus*), fitted with very high frequency or global positioning system collars in the Rocky Mountains of southeast British Columbia, exhibited straight-line seasonal movements ranging from <4 km to 109 km. Movement was almost entirely along the floor of both low- and high-elevation valleys, although there was some use of mid-elevation mountainsides during early winter. Spatial locations of deer spanned 891–2234 m above sea level. Seasonal movements of these deer from a single winter range extended to two provinces, three national parks, one provincial park, non-park provincial Crown land, and private land. Deer populations with similar movement patterns may be most effectively managed by considering their extensive movements and coordinating approaches across jurisdictions.

Key words: Kootenay National Park; *Odocoileus virginianus*; seasonal movement; summer range; White-tailed Deer; winter range

Introduction

White-tailed Deer (*Odocoileus virginianus*) inhabit a range of ecosystems across North and South America. Some individuals and populations exhibit migration (round-trip movements between distinct seasonal ranges, *sensu* Berger 2004) of tens of kilometres, with greater movements typical in northern or mountainous locations (Baumeister 1992; Demarais *et al.* 2000; Robinson *et al.* 2002; Nelson *et al.* 2004; Brinkman *et al.* 2005; Stewart *et al.* 2011). In some study areas, individuals may be sedentary, facultative migrators, or obligate migrators (Sabine *et al.* 2002; Brinkman *et al.* 2005; Fieberg *et al.* 2008; Grovenburg *et al.* 2011). Deer on low-quality winter range may be more likely to migrate as a result of density-dependent competition (Henderson *et al.* 2018). During spring and summer, an advancing line of greening vegetation offers ungulates in the Rocky Mountains the opportunity to follow high-quality habitat up slope (Merkle *et al.* 2016; Middleton *et al.* 2018).

Based on long-term roadside surveys and incidental observations, White-tailed Deer in Kootenay National Park (KNP), British Columbia (BC), Canada, are common from spring through fall, but absent or nearly so during winter (S. Wrazej unpubl. data). Considering those observations in the context of the strong elevation gradient in the area, seasonal elevation differences reported for nearby deer populations (Robinson *et al.* 2002; Hoekman *et al.* 2006), and an expectation of generally low-quality winter ranges for deer in snowy, mountainous areas in the northern part of their range, I speculated that deer summering in the park overwintered at lower elevations south of the park. I collared adult female White-tailed Deer south of the park and within the park, and investigated their movement patterns. Deer were monitored for variable periods and could not all be confirmed to make return movements (migrations); thus, I use the more general term "seasonal movement". I report on seasonal movements and elevation-use patterns of these collared deer, including in relation to jurisdictional boundaries potentially affecting management regimes.

Study Area

The Beaverfoot and upper Kootenay Rivers are part of the Columbia River watershed of southeast BC (Figure 1). Their headwaters rise in the same valley in the Rocky Mountains. From there, the Beaverfoot River flows generally north by northwest into Yoho National Park where it joins the Kicking Horse River, which eventually exits the Rocky Mountains and flows into the Columbia River in the Rocky Mountain

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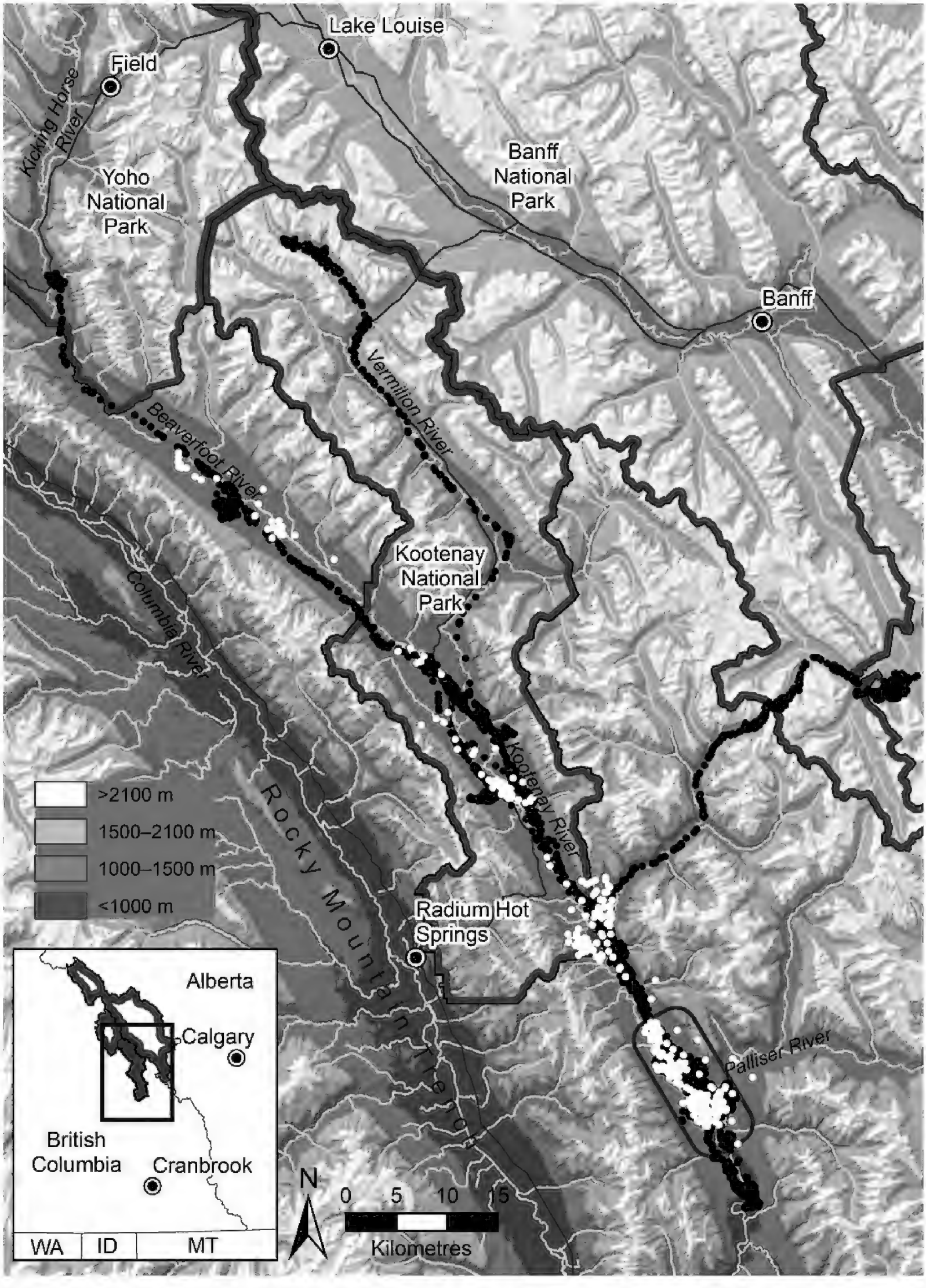

FIGURE 1. Pooled location data from 19 female White-tailed Deer (*Odocoileus virginianus*) fitted with global positioning system (black dots) or very high frequency (white dots) collars in the upper Kootenay River valley of British Columbia, 2011–2016. Winter range is oval in lower right.

Trench (hereafter "Trench"). The Kootenay River flows south by southeast, passing through and beyond KNP before exiting the Rockies into the Trench. The elevation of the valley bottom is ~1250 m at the headwaters and ~1050 m at the downstream ends of the parks. Mountains adjacent to the rivers reach a maximum elevation of 2400–3000 m.

Leading tree species vary with elevation and location, but along the valley bottoms are primarily Lodgepole Pine (*Pinus contorta* Douglas ex Loudon), Engelmann Spruce (*Picea engelmannii* Engelmann), Trembling Aspen (*Populus tremuloides* Michaux), Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), Western Larch (*Larix occidentalis* Nuttall), and, locally, Western Red Cedar (*Thuja plicata* Donn ex D. Don). At higher elevations, leading tree species are Engelmann Spruce and Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall). Vegetation is dominated by mixed-age, mixed-species stands of those conifers interspersed with burns, wetlands, cutblocks from past logging (outside of parks), and non-forested areas on the highest peaks. This variety includes the range of grass, shrub, and open forest cover types normally selected by deer nearby and also the greater canopy cover selected under deep snow conditions (Hoekman *et al.* 2006). There is no agriculture within the study area.

Methods

Deer were captured in Clover traps (VerCauteren *et al.* 1999) baited with either hay and liquid and dried commercial deer attractants or hay, salt, apple, and dried molasses. One deer was immobilized by free-range darting (Dan-Inject APS, Børkop, Denmark) using a medetomidine–ketamine mixture (Caulkett *et al.* 2000). Deer captures were undertaken primarily in February 2014 on a winter range 15–20 km south of the southern boundary of KNP (Figure 1). This was at the confluence of the Kootenay and Palliser Rivers, at an elevation of 950–1100 m. Capture also occurred during November 2011, April 2012, and November–December 2015 within or beside anthropogenic forest openings in KNP, at ~1160 m elevation.

Females <11 months old and all males were released. All other females were fitted with collars, either global positioning system (GPS; G2110D, Advanced Telemetry Systems, Isanti, Minnesota, USA) or very high frequency (VHF; LMRT-2, Lotek Wireless, Newmarket, Ontario, Canada). One female originally fitted with a VHF collar was later recaptured and fitted with a GPS collar. GPS collars attempted fixes hourly, were programmed to detach about 10 months after collaring, and were downloaded on retrieval. VHF-collared deer were relocated on an approximately two-week schedule through ground monitoring. Aerial monitoring was undertaken twice in late winter of the first year, when only one deer was collared and snow depth prevented ground access, and once for all deer in another year as they left the winter range when not all deer could be located from the ground.

Maximum straight-line movements were determined for each deer monitored from at least January or February to July or August or the reverse for one or more years, i.e., for those with potential to demonstrate seasonal movements. Universal Transverse Mercator coordinates were used to calculate Euclidean distances between the most distant points. Elevations reported here are only as recorded onboard GPS collars because, in the mountainous study area, relatively small horizontal errors would translate into considerable elevation errors if extracted via a geographic information system, especially for VHF collar data. All maximum and minimum elevation records were confirmed to be within clusters of sequential locations and, hence, unlikely to reflect significant GPS error. To represent movement vectors at an appropriate scale, sequential records of deer locations were manually approximated graphically. Where overlapping individuals were not distinguishable, these representations were further linearized for visual clarity.

Results

Time from date of collaring to death, collar drop, or cessation of monitoring ranged from 299 to 1417 days for the 10 VHF-collared deer ($\bar{x}$ = 667, SD 295) and from 166 to 320 days for the nine GPS-collared deer ($\bar{x}$ = 286, SD 56) for which seasonal movements were calculated. Maximum straight-line movements (Figure 2) ranged from 6.1 to 82.4 km for VHF-collared deer ($\bar{x}$ = 33.0 km, SD 27.3) and from 3.4 to 109.2 km for deer with GPS collars ($\bar{x}$ = 48.7 km, SD 40.0). Among GPS-collared deer, maximum elevations ranged from 1199 m to 2234 m and minimum elevations from 891 m to 997 m (pooled sample: 10% < 1010 m, 10% > 1382 m). Variation in elevation use was evident during summer, with two deer occurring at maximum elevations (>1900 m) at a time when all others were below 1500 m, and during early winter when two deer used elevations above 1600 m while others were below 1300 m (Figure 3).

Seventeen deer were not recorded outside the contiguous Kootenay–Beaverfoot–Kicking Horse valley (Figures 1 and 2), but two moved into a major tributary valley or crossed the Continental Divide into Alberta. All 19 occurred for at least part of the year on provincial Crown land in BC, of which at least nine also made use of Kootenay, Yoho, or Banff national parks, one of Spray Valley Provincial Park,

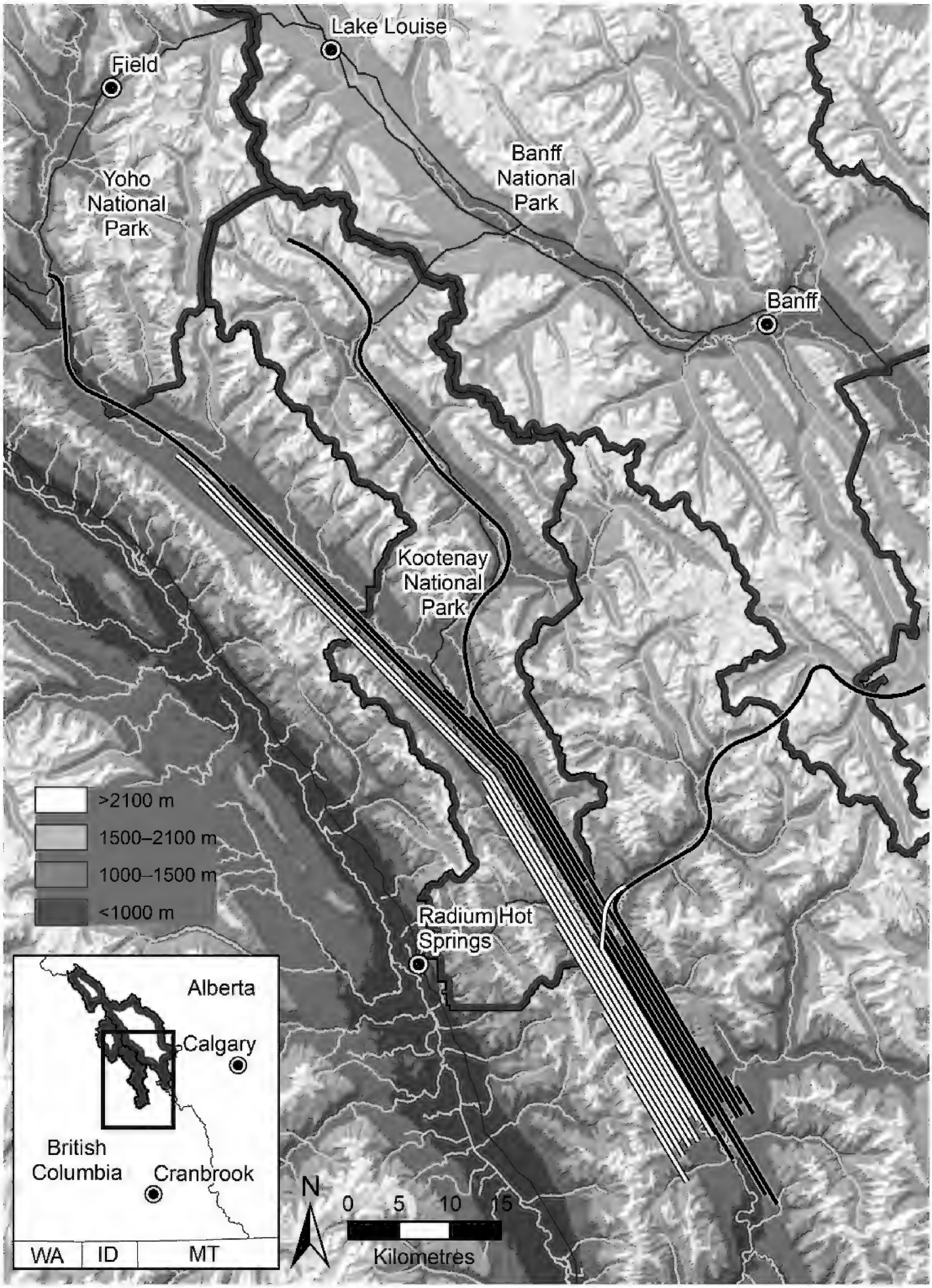

FIGURE 2. Maximum extent of movements of 19 female White-tailed Deer (*Odocoileus virginianus*) fitted with global positioning system (black lines) or very high frequency (white lines) collars in the upper Kootenay River valley of British Columbia, 2011–2016. Movements are presented as linear vectors for visual clarity.

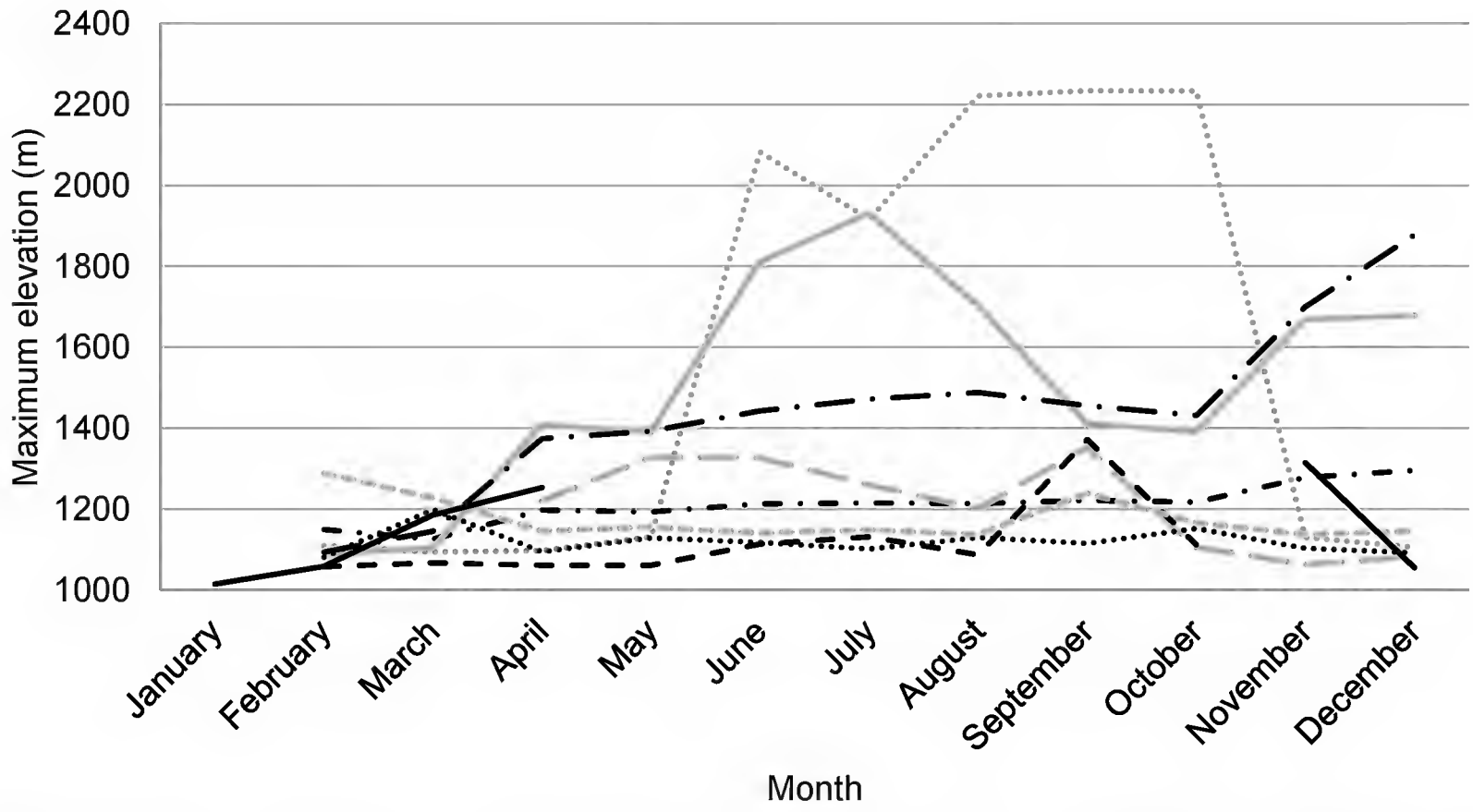

FIGURE 3. Maximum elevation per month of nine White-tailed Deer (*Odocoileus virginianus*) captured in the upper Kootenay River valley of British Columbia and fitted with global positioning system collars, 2012–2016.

Alberta, and five of private land in BC. Of the nine using one or more national parks for part of the year, at least eight were on Crown or private land in BC during part or all of the current regular, youth, or bow-only "antlerless" hunting seasons from October through December (MFLNRORD 2018). One collared deer summered south of the winter range; all others were generally north.

Discussion

Given the lower frequency of monitoring of VHF collars and potential effects of limited access on manual monitoring, data from VHF collars likely underrepresent deer movements and use of high elevations relative to GPS collars. The apparently shorter maximum movements of VHF-collared deer despite longer duration of monitoring may reflect that. However, for both collar types, a wide range and broadly similar distribution of maximum movements was recorded. Even with the possibility that some deer movements reported in other studies may have represented dispersals, mean and maximum seasonal movements reported here are greater than values reported from nearby studies in the mountains of BC and northwest United States (Morgan 1993; Secord 1994; Robinson *et al.* 2002; Hoekman *et al.* 2006) and in 10 earlier studies from the same region summarized by Baumeister (1992: 56) and similar to those observed by Baumeister (1992). Compared with the findings of most of those authors and Henderson *et al.* (2018), maximum movements of the deer in my study were an order of magnitude greater.

A range of elevation-use strategies was apparent. Use of minimum elevations was similar among individuals, but maximum elevations varied considerably. Most deer activity was along the floor of the main valley in which they wintered. When deer left that valley, movements typically followed the floors of the tributary valleys in which they travelled. However, the higher elevations of those tributaries, along with some limited forays from the main valley to adjacent mountain slopes, were associated with several other patterns of elevation use. Some deer occurred at high elevations for at least part of the summer, and some moved to relatively high elevations during early winter.

Relatively long-distance movement by deer in this study area may have reflected the abundance and broad distribution of moderate- to high-elevation summer habitats and the limited elevation gradient at valley-floor positions, such that any deer gaining the advantage of following the wave of greening vegetation upslope (Mysterud 2013; Merkle *et al.* 2016, Middleton *et al.* 2018) without leaving valley floors would be obliged to move considerable distances in this landscape. The existence of a wintering population in an elevated valley proximal to the Trench is notable. The Trench is as close as 15 km to summer and winter activity (Figure 1), is accessible via several passes or downstream movement, is at lower elevations with less snow and warmer winter temperatures, includes agricultural fields and extensive riparian areas, and

is notable for an abundant large-mammal fauna and high-quality winter range (Benson 1970) including for deer. Delaying movement to winter ranges is advantageous to some ungulates (Mysterud 2013), yet White-tailed Deer are poorly adapted to snow (Stelfox and Taber 1969; Telfer and Kelsall 1984). For deer in my study, further travel through snow to reach the Trench may be prohibitive late in the season despite apparently higher-quality habitat used by other deer in the Trench. Alternatively, the shorter return distance to summer habitats and the ability to more precisely gauge the initiation of green-up may offer advantages to remaining within the mountains during winter. Additional collaring on summer ranges within this region of the Rocky Mountains would indicate whether some White-tailed Deer summering there do seasonally join other deer in the Trench.

Deer wintering in the upper Kootenay River valley occurred in Kootenay and Yoho national parks in BC, Banff National Park and Spray Valley Provincial Park in Alberta, and both private land and non-park Crown land in BC. For a species as resilient as White-tailed Deer (Halls 1978), a lack of protective management across jurisdictions is unlikely to have the severe population effects experienced by many migratory ungulates (Bolger *et al.* 2008). However, management goals for resource extraction, fire, deer hunting, predator hunting and trapping, ecological integrity, and recreation have the potential to constrain or enhance deer populations and movements. Cross-jurisdictional differences may influence the ability of any agency to achieve its wildlife or ecosystem objectives. For example, managing predators or enhancing habitat to benefit deer would have less effect if done only on a portion of the population's annual range, and maintaining a naturally functioning system may be affected by activities on other land bases, such as hunting during the "antlerless" deer season on provincial and private land. It would be prudent for resource managers to coordinate their efforts with nearby jurisdictions or at least consider the effect of extensive seasonal movements when managing White-tailed Deer in the Rocky Mountains.

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Sharp-tailed Grouse (*Tympanuchus phasianellus*) population dynamics and restoration of fire-dependent northern mixed-grass prairie

Robert K. Murphy[1,2,*] and Karen A. Smith[1,3]

[1]United States Fish and Wildlife Service, Des Lacs National Wildlife Refuge Complex, Kenmare, North Dakota 58746 USA
[2]Current address: Eagle Environmental, Inc., 12 Longview Road, Sandia Park, New Mexico 87047 USA
[3]Current address: 8210 88th Street NW, Kenmare, North Dakota 58746 USA
[*]Corresponding author: murph@eagleenvironmental.net

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Abstract

Case studies of Sharp-tailed Grouse (*Tympanuchus phasianellus*) population dynamics before and during re-introduction of fire to northern mixed-grass prairies that lacked fire for multiple decades are unavailable. At a 108-km^2 northern mixed-grass prairie refuge in North Dakota, fire was suppressed from the early 1900s through late 1970s. Nine management units (total area 16.8 km^2, 15.7% of the refuge) received initial prescribed fire treatments during 1979–1984. The mean annual density of male Sharp-tailed Grouse attending leks on these units during 1981–1985 (9.0 males/km^2) was twice that on the same units during 1961–1965 (4.2 males/km^2), amid the fire exclusion era; nonoverlap of 90% CIs encompassing the means suggested a significant treatment effect. However, densities of males on units managed without prescribed fire during 1961–1965 and 1981–1985 did not change between the two periods. By 1987, fire had been re–introduced to >50% of the refuge overall. Mean annual abundance (i.e., total numbers) of lekking males on the entire refuge did not differ between 1961–1965 and 1981–1985 but was significantly greater during 1989–1993 than during 1961–1965 and 1981–1985. Changes in density and abundance of lekking males coincided with fire-induced reductions in woody cover and increases in herbaceous cover. Our study illustrates the marked capacity of Sharp-tailed Grouse to respond to reductions of tree and shrub cover resulting from prescribed fire in northern mixed-grass prairie and the species' attraction to habitat disturbance in general.

Key words: Sharp-tailed Grouse; *Tympanuchus phasianellus*; northern mixed-grass prairie; prairie management; prescribed fire; North Dakota

Introduction

During the 1900s, tree and shrub cover increased markedly on present-day national wildlife refuges in the northern mixed-grass prairie (NMGP) region of North America's Great Plains, mainly due to fire suppression (Grant and Murphy 2005). Fire-intolerant Trembling Aspen (*Populus tremuloides* Michaux), Silverberry (*Elaeagnus commutata* Bernhardi ex Rydberg), and Western Snowberry (*Symphoricarpos occidentalis* Hooker) were common tree and shrub species that proliferated. Some species of grassland-dependent passeriform birds that bred on the refuges became rare or absent in areas invaded by trees and shrubs (Madden *et al.* 1999; Grant *et al.* 2004; Murphy and Smith 2007). Sharp-tailed Grouse (*Tympanuchus phasianellus*), a conspicuous member of the NMGP breeding bird community, may abandon landscapes that become invaded by trees and shrubs in the absence of fire, e.g., in Aspen Parkland (Caldwell 1976; Moyles 1981; Berger and Baydack 1992). However, there are no published reports of changes in numbers of the species during years encompassing prescribed fires to restore grassland landscapes invaded by woody vegetation in the NMGP region.

While compiling a case study on the management of 108-km^2 Lostwood National Wildlife Refuge (LNWR), centred in the NMGP region, we found that data on annual counts of Sharp-tailed Grouse and concurrent records of fire re-introduction to the area after roughly 60 years of fire exclusion could contribute to the knowledge of fire's role in Sharp-tailed Grouse management. Moreover, the case study could be supported by published data on changes in dominance of woody versus herbaceous vegetation associated with prescribed fire on the refuge (Madden *et al.* 1999; Murphy and Smith 2007; Smith and Murphy 2007) given a major refuge management objective: to restore the historic (before settlement by Euro-

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American peoples) balance of woody versus herbaceous vegetation to favour native grassland bird species and other native wildlife (U.S. Fish and Wildlife Service 1998). Our first study objective, carried out at a local spatial scale, was to compare the density (i.e., number/km^2) of lekking male Sharp-tailed Grouse on prairie management units during 1961–1965, amid the fire exclusion era, to the density of lekking males on the same units under initial prescribed fire treatments during 1981–1985. Our second study objective, pursued at a landscape scale, was to compare overall abundance (i.e., total number) of lekking male Sharp-tailed Grouse on all of LNWR among three 5-yr periods: (1) 1961–1965, amid the fire exclusion era; (2) 1981–1985, the initial fire re-introduction period; and (3) 1989–1993, after >50% of the refuge had been treated by prescribed fire at least once. As part of this objective, we also examined relationships between abundance or density of lekking male Sharp-tailed Grouse and fire history, i.e., number of fires conducted, across management areas of the entire refuge.

Methods

LNWR, in Burke and Mountrail counties, northwestern North Dakota (48.617°N, 102.450°W), is rolling to hilly native prairie (55% of refuge area) and tame grasslands (21%) interspersed with about 4000, 0.1- to 224-ha wetlands (20%; Murphy 1993). Before settlement by Euro-Americans in the early 1900s, the upland landscape was mixed-grass prairie dominated by needlegrasses (*Nassella viridula* [Trinius] Barkworth, *Hesperostipa comata* Oldham and Brinker, *Heterostipa spartea* [Trinius] Barkworth), Western Wheatgrass (*Pascopyrum smithii* [Rydberg] Á. Löve), Blue Grama (*Bouteloua gracilis* [Kunth] Lagasca ex Griffiths), and a variety of native forb species (Barker and Whitman 1988). Shrubs probably covered ~5% of the uplands and trees were rare (U.S. Soil Conservation Service 1975). Patches of tree-size Trembling Aspen began to appear by the 1930s (as detected in aerial photos) after 10–20 years of active fire suppression (Murphy 1993). The density and mean size of aspen patches on LNWR increased from 1.5 patches/km^2 and 0.13 ha in the mid–1930s, when the refuge was established, to 4.8 patches/km^2 and 0.36 ha in the early 1980s, respectively. Shrub cover dominated by Western Snowberry increased from ~25% in the mid–1930s to >50% by the early 1980s.

Counts of lekking male Sharp-tailed Grouse can yield reliable population indices if done within narrow constraints with bias accounted for (Drummer *et al.* 2011). All Sharp-tailed Grouse leks on LNWR were located systematically in early spring annually during 1961–1965 and 1981–1993, following standard guidelines (Kirsch 1956). Each lek had at least two males by definition. To maximize accuracy, males were counted two to four times on each lek between 0.5 h before sunrise to 2 h after sunrise during mid-April through early-May, encompassing the peak period of lek attendance by breeding hens in the region (Connelly *et al.* 1998). Males on some leks could be counted by observation with binoculars from nearby hilltops. Most leks, however, were higher than their surroundings such that some or most males could not be viewed directly from any single location. In such a case, the observer crept to within ~3–10 m of the lek's edge and listened to determine whether females were present; acoustic displays by male Sharp-tailed Grouse on leks are distinctly more intense when females are there (Connelly *et al.* 1998). If females were present, they would flush immediately when the observer stood slowly. In contrast, males typically hesitated to flush for several seconds after all females flushed, then flushed and flew together in a cohesive flock. The flocked males typically could be counted by the observer at least twice before landing or flying from view. The same procedure would be followed at the respective lek on at least one other morning until counts of total males on the lek were consistent among mornings.

To address our first objective of comparing the density of lekking male Sharp-tailed Grouse on management units during 1961–1965 to the density of lekking males on the same units during initial prescribed fire treatments ~20 years later, we used concurrent changes in densities of lekking males on units not prescribe-burned as a baseline for comparison. Relying on refuge records, we categorized the 1940–1985 management history of units as either (1) grazed by cattle <19 years; (2) grazed by cattle >29 years; (3) prolonged rest; (4) treated by prescribed fire during 1979–1984; or (5) burn perimeter (Table 1, Figure 1). Prescribed fires at LNWR were conducted by using a surround technique, described in Murphy and Smith (2007). Most fires consumed >80% of aboveground vegetation (Table 2). We categorized the area within 0.8 km of burn units as burn perimeter (a mix of grazed <19 years, grazed >29 years, and prolonged rest categories; Figure 1) because prescribed fires could indirectly influence densities of lekking male Sharp-tailed Grouse on adjacent management units, and 0.8 km approximates the mean distance between the species' leks and nest sites (reviewed in Connelly *et al.* 1998).

We could not formally test for differences in density of lekking male Sharp-tailed Grouse among management history categories because management treatment types were not assigned randomly to the various units, and prolonged rest and burn perimeter categories were represented by only one and

TABLE 1. Management history of prairie management units at Lostwood National Wildlife Refuge in northwestern North Dakota during 1940–1985.

Unit category	Number of units	Total area (km^2)	Management history description
Grazed <19 years*	3	13.8	Grazed by cattle at light stocking rates (0.4–0.6 Animal Unit Months/ha) during July–October every 1–4 years during 1940–1979 and rested during 1980–1985
Grazed >29 years†	3	16.0	Grazed by cattle at light stocking rates (0.4–0.6 Animal Unit Months/ha) during July–October every 1–2 years during 1940–1979 and rested during 1980–1985
Prolonged rest	1	7.1	Not grazed or prescribe-burned
Burned 1979–1984	9	16.8	Rested and periodically grazed 1940–1978 then prescribe-burned one, two, or three times in late spring or summer during 1979–1984, with 2–3 years between prescribed fires on units burned two or three times‡
Burn perimeter	2	19.2	Not prescribe-burned; a mix of grazed <19, grazed >29, and prolonged rest categories

*Range 11–18 years.
†Range 30–36 years.
‡Table 2 presents detailed 1979–1984 fire treatment history for each unit.

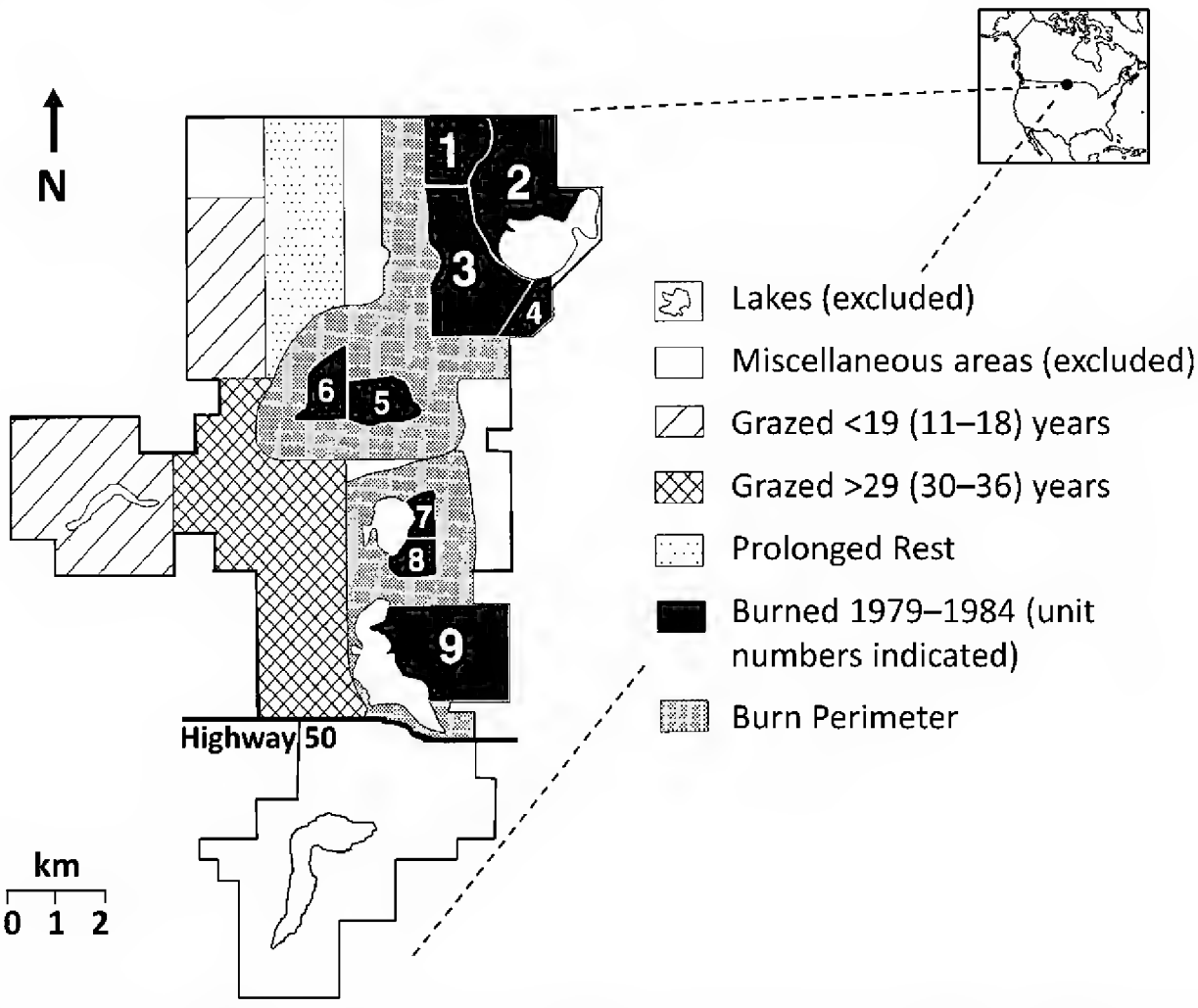

FIGURE 1. Location and management history of prairie management units on Lostwood National Wildlife Refuge in northwestern North Dakota as of 1981–1985, when density (individuals/km^2) of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) displaying on leks in spring was documented annually on units of five management categories. These were compared to densities of lekking males documented on the respective units during 1961–1965. The refuge area south of Highway 50 was excluded from the comparison of densities as it was open to hunting of Sharp-tailed Grouse. Inset map (upper right) indicates the study area (black dot) in relation to North America's northern mixed-grass prairie region (grey shaded).

two units, respectively (Table 1). Our conclusions were thus limited. We considered, however, that tentative evidence of a treatment effect might be implied for a given management history category if 90% CIs around the respective 1961–1965 and 1981–1985 mean densities did not overlap. Moreover, our approach to assessing male Sharp-tailed Grouse density in relation to prescribed fire included counts of lekking males on all prescribed fire units each spring, such that in a given spring, residual vegetation was

TABLE 2. Size, year of treatment, and thoroughness of burns on prairie management units treated by prescribed fire on Lostwood National Wildlife Refuge in northwestern North Dakota during June, July, or August, 1979–1984.

Unit number	Area (km²)	Year					
		1979	1980	1981	1982	1983	1984
1	1.0	c*		c		c	
2	3.7		b		c		
3	5.0			c		c	
4	0.5	a		b		c	
5	0.9	c			a	b	
6	1.0				c		b
7	0.4				c		
8	0.5				c		c
9	3.8				c		

*Approximate percentage of above-ground live and residual vegetation removed by prescribed fire: (a) 35–50%; (b) 51–80%; (c) >80%.

limited on units that had been burned the previous summer. This provides for a conservative picture of the species' response to prescribed fire because in the first spring after summer fires, vegetation on LNWR is relatively short and sparse (Madden *et al.* 1999), less than optimal for females seeking nest sites. Because male Sharp-tailed Grouse compete for space on leks near areas frequented by females seeking ideal nesting cover (Gratson 1988), lek attendance by males is likely to be reduced during the first spring after summer fires. We acknowledge that small numbers of male Sharp-tailed Grouse may not attend leks in some years or do so infrequently (Gratson *et al.* 1991) but believe this possibility would negligibly influence our conclusions.

During 1986–1993, following the initial prescribed fires, incrementally greater proportions of LNWR were treated by prescribed fire such that units lacking prescribed fire histories including burn perimeter became less and less available. This change hindered longer-term comparison of male Sharp-tailed Grouse density among management history categories. We could, however, assess landscape-level changes in abundance (i.e., total numbers) of lekking male Sharp-tailed Grouse across all of LNWR in relation to prescribed fire. For our second objective, we sought to examine abundance of lekking males in the first five-year period after 1985 during which >50% of the refuge was treated with prescribed fire. We also sought a five-year period during which mean annual precipitation, from one year before the start to one year before the end of the period, was similar to that in the 1961–1965 baseline (40.2 cm) and 1981–1985 initial prescribed fire periods (41.7 cm). For a given year, we considered precipitation level in the previous year as a key potential confounding factor in our comparison because it can markedly influence survival of Sharp-tailed Grouse in general (Cartwright 1944). The years 1989–1993 met these two criteria (55–64% of refuge burned; 40.0 cm mean annual precipitation during 1988–1992), except that an unnaturally severe wildfire burned a 22.7-km² unit of the refuge in August 1988. We considered the wildfire an anomaly because it occurred when there was an abnormally high buildup of residual vegetation combined with ambient temperature, relative humidity, fuel moisture, and windspeed conditions far exceeding bounds for conducting prescribed fires (U.S. Fish and Wildlife Service unpubl. data). The wildfire burned into the humus layer and in many places to mineral soil, removing all residual and live, aboveground herbaceous and woody vegetation except for ~40% of tree-size Trembling Aspen and scant patches of Western Snowberry. Therefore, we replaced the following spring's (1989) count of lekking males with like data from spring 1987, the only year following prescribed fire treatment (July 1986) of the area, although total precipitation in the previous year (1986) was slightly greater (45.7 cm) than the 1988–1992 mean. Last, we considered the August 1988 wildfire to be, in effect, a 1989 prescribed fire with regard to its influence on residual vegetation and numbers of lekking male grouse the following spring.

We therefore consider the 1989–1993 period as a landscape-level prescribed fire period (hereafter the Landscape Fire period). In a similar vein, we hereafter refer to the 1961–1965 period, that neared the end of ~60 years of fire suppression, as the Fire Exclusion period, and the 1981–1985 years associated with initial prescribed fire treatments as the Initial Fire period.

During the mid-1980s, LNWR was partitioned into 20 "management blocks" (MBs) averaging 4.7 km² in area (SE = 1.0, range = 0.6–22.7). To assess whether total abundance of lekking male Sharp-tailed Grouse on LNWR changed between any two

of the three time periods, we first combined small (<5 km^2), adjoining MBs into five MB groups composed of two to four MBs each. Each of five other "groups" were represented by one large MB. Thus, a total of 10 MB groups were available to provide adequate sample sizes for a matched-pairs analyses of temporal change in abundance of lekking male grouse. We next summed the total number of lekking males in each MB group, for each year in each of the three time periods, then calculated the mean annual abundance of lekking males for each MB group by period. To test for a difference in total abundance between two given periods, we paired the periods' annual means for each MB group and used the non-parametric Wilcoxon matched-pairs signed-ranks test (Daniel 1990) to assess whether overall means of the paired observations differed. Specifically, we used a two-tailed version of the test with α set at 0.1 to determine whether total abundance of lekking male Sharp-tailed Grouse differed between (1) the Fire Exclusion and Initial Fire periods, (2) Initial Fire and Landscape Fire periods, and (3) Fire Exclusion and Landscape Fire periods. A one-tailed test would seem appropriate based on knowledge that Sharp-tailed Grouse abundance can increase when prescribed fire is incorporated into the habitat disturbance regime (Kirsch and Kruse 1972; Kirsch *et al.* 1973). However, one-tailed Wilcoxon tests performed with small sizes, as in our case (10 matched pairs), can result in incorrect *P*-values (Mundry and Fischer 1998), so we used the more conservative two-tailed approach. Before conducting the tests, we plotted distributions of the differences between pairs and found the distributions to be reasonably symmetrical, an assumption of the Wilcoxon signed-ranks test (Daniel 1990).

Finally, we categorized each MB by the number of prescribed fires (i.e., fire history) applied to it during 1979–1992, from none up to four (Figure 2). However, most area covered by two MBs in a three or four burns category also was treated with intensive, prolonged grazing by cattle during two and three (respectively) late spring-early summer seasons of the Landscape Fire period. So, we placed them in a unique fire history category named "3 or 4 Burns plus Grazing" (3+G in Figure 2). The 22.7-km^2 unit that experienced a severe wildfire in August 1988 was placed in its own MB category, named "1 Burn plus 1 Wildfire" (1+W), because the wildfire event distinguished it from other MBs; this MB also was unique due to its large size, nearly four times larger than any other. We used non-overlap of 90% CIs encompassing means as tentative evidence of differences in abundance of lekking male Sharp-tailed Grouse among fire history categories in different periods. We also calculated period-specific densities of lekking male Sharp-tailed Grouse for each fire history category.

Results

Based on non-overlapping 90% CIs (Figure 3), the mean annual density of lekking male Sharp-tailed Grouse on prairie management units that were treated by prescribed fire during the Initial Fire period was more than double what it was on the same units ~20 years earlier, during the Fire Exclusion period. Meanwhile, densities of lekking males did not differ between the periods on rested, grazed, and burn perimeter units, based on substantial overlap among 90% CIs (Figure 3).

Across all of LNWR, the mean annual abundance of lekking male Sharp-tailed Grouse did not differ be-

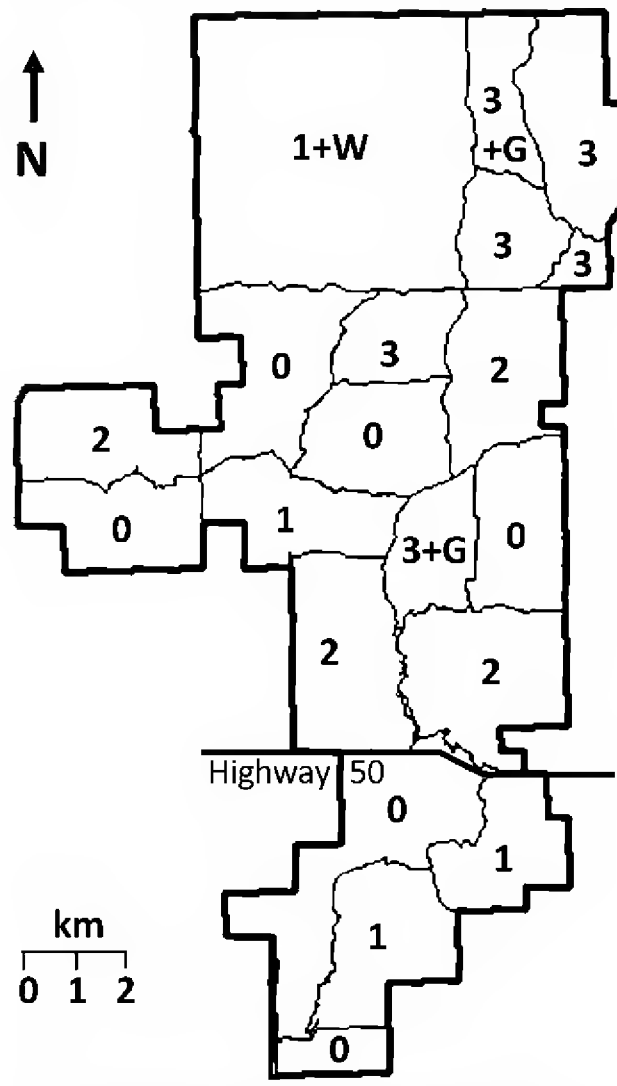

FIGURE 2. Number of prescribed fires applied during 1979–1992 on management blocks at Lostwood National Wildlife Refuge in northwestern North Dakota. Wildfires had been effectively suppressed on the area before 1979. Management block boundaries were designated during the mid-1980s.

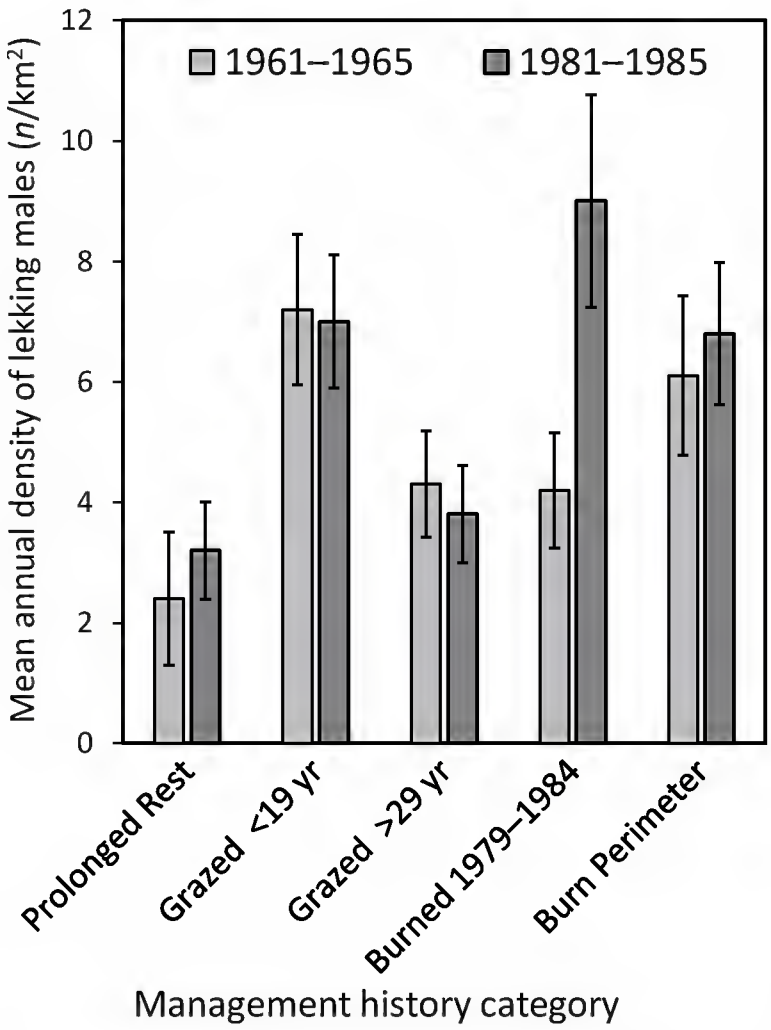

FIGURE 3. Mean annual densities (individuals/km²) of lekking male Sharp-tailed Grouse (*Tympanuchus phasianellus*) at Lostwood National Wildlife Refuge in northwestern North Dakota during 1961–1965 and 1981–1985 on multiple prairie management units of each of five management history categories (see Table 1); density was assessed on the same units of each category during both time periods. After ~60 years of fire suppression, prescribed fire was re-introduced to the refuge during 1979–1984, specifically on units in the Burn 1979–1984 category. Error bars are 90% CIs.

tween the Fire Exclusion and Initial Fire periods ($W^+ = 23.5$, $n = 10$, $P = 0.70$; Figure 4). However, mean annual abundance of lekking male Sharp-tailed Grouse across all of LNWR was significantly greater during the Landscape Fire period than during the Fire Exclusion ($W^+ = 7$, $n = 10$, $P = 0.04$) and Initial Fire periods ($W^+ = 2$, $n = 10$, $P = 0.006$; Figure 4). A 32% increase in mean annual abundance from the Initial Fire to Landscape Fire periods coincided with a substantial rise in the percentage of LNWR treated by prescribed fire at least once, from 6.0–15.7% during 1979–1984 to 53.4–63.1% during 1987–1992 (Figure 4). Up to 1185 lekking males were recorded in one year (1992), representing an overall density of 12.6 males/km² (based on 94.2 km² total refuge area excluding major lakes). Most of the increase in total numbers arose from MBs burned once or twice between 1979 and 1992 (Figure 5a). During this period, density of lekking males seemed consistently high across all categories of number of fires experienced (range of means = 9.7 to 10.7 males/km²; range of CIs, ± 1.7 to ± 2.7), except for the "3 or 4 Burns plus Grazing" category, where no lekking males were detected, and the "0 Burns" category (Figure 5b).

Discussion

Our case study of the re-introduction of fire to a large tract of NMPG deprived of fire for >60 years and associated changes in density and abundance of lekking male Sharp-tailed Grouse is unique for the NMGP region. It may well illustrate the species' marked capacity to respond to the reduction of trees and shrubs by prescribed fires in a prairie ecosystem, and to major perturbations in general. During the 1981–1985 Initial Fire period, the mean annual density of lekking males was about two-fold greater on prairie management units receiving initial prescribed fire treatments than on the same units during the Fire Exclusion period two decades earlier, when the units had been managed by prolonged rest or rest and grazing. This increase occurred even though the Initial Fire dataset included many counts of males on units treated by prescribed fire in previous summers. Scattered unburned patches of vegetation may have attracted nesting females to such areas; unburned "skips" comprised a mean of 14.5% of three units burned during 1982–1984 (Kruse and Piehl 1984). Moreover, the lack of change in male densities between the Fire Exclusion and Initial Fire periods on all but the burn units suggests that the increased density of lekking male Sharp-tailed Grouse on burn units can be attributed to the general growth in bird numbers on those units rather than just shifts in locations of males from other units.

In contrast with the markedly increased density of male Sharp-tailed Grouse between the Fire Exclusion and Initial Fire periods on management units in the burn category, we found no evidence of concurrent change in male density on units categorized as either prolonged rest, <19 years grazed, or >29 years grazed. Under the latter management regimes, however, densities likely would have declined during time intervals exceeding two decades, as trees and shrubs continued to displace grass- and forb-dominated prairie. Indeed, in the absence of fire for roughly six decades, much of the NMGP refuge had become aspen parkland, with some 2.59-km² sections having >15 aspen tree patches (Murphy 1993). In southern Manitoba, Berger and Baydack (1992) documented a severe decline in the number of Sharp-tailed Grouse leks as prairie gradually transformed into Trembling Aspen-dominated forest during only 21 years of fire suppression; on average, the birds abandoned a given lek if forest cover within 1 km exceeded 56%. Tree-size Trembling Aspen cover at LNWR averaged far less, only about 0.6% in 1969 and 0.7% in

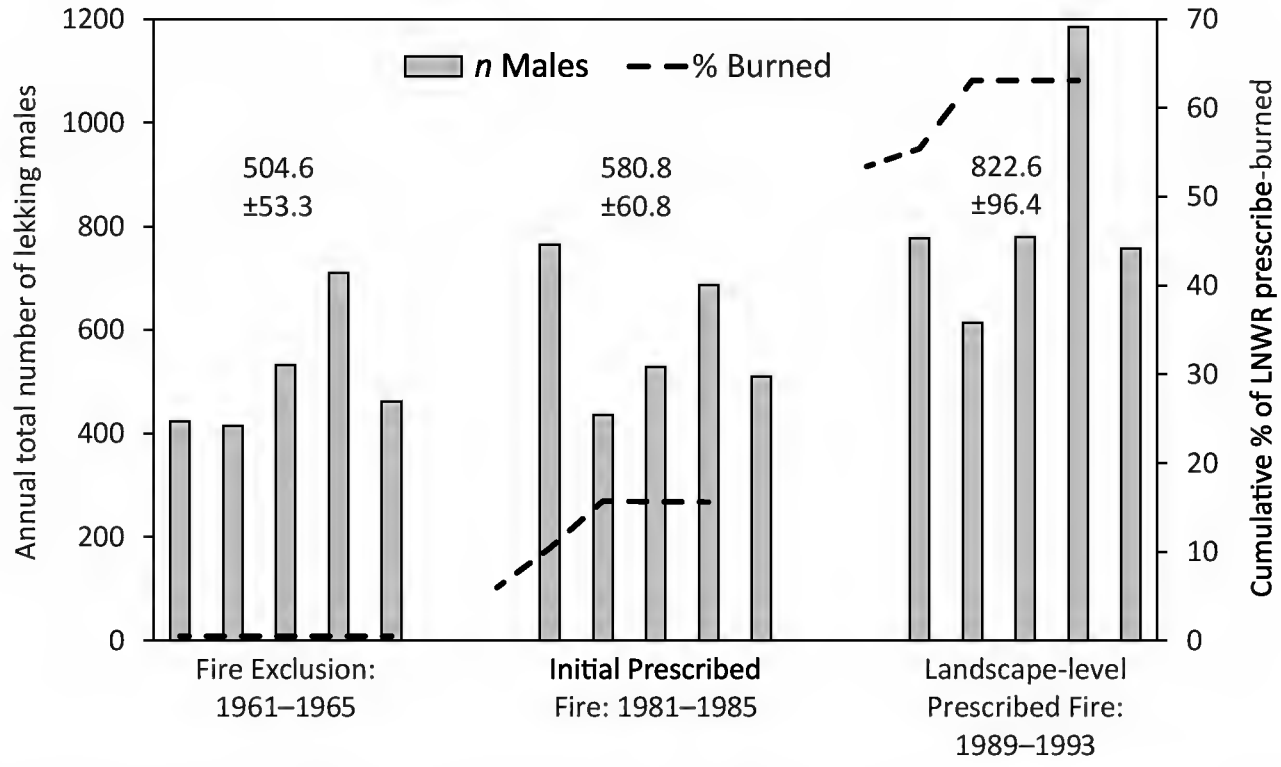

FIGURE 4. Change in annual abundance, i.e., total number, of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) attending leks in spring at Lostwood National Wildlife Refuge, northwestern North Dakota during three historic time periods in relation to percentage of the refuge treated by prescribed fire at least once beginning in 1979, after ~60 years of fire suppression. Prescribed fires were conducted during late spring through summer. Due to an artificially severe wildfire on a 22.7-km^2 management block in August 1988, the 1989 count of lekking males was replaced by like data from 1987, following the management block's first prescribed fire in 1986 (see text). Above each five-year group of columns is the respective group mean ± 1 SE.

1985 (Figure 4 in Grant and Murphy [2005]). Thus, the near-complete removal of aspen trees at LNWR via burning or combinations of grazing and burning (Smith and Murphy 2007) probably contributed less to increases in male Sharp-tailed Grouse abundance than did the conversion of much shrub cover (mainly Western Snowberry and Silverberry) to grass-forb cover types via prescribed fire (Madden *et al.* 1999). Such a conversion has been critical in restoring other key members of the refuge's grassland bird community. For example, the endemic Sprague's Pipit (*Anthus spragueii*) and Baird's Sparrow (*Ammodramus bairdii*) were absent and rare, respectively, on two 90-ha tracts rested and lightly grazed for >40 years but reappeared and increased after four prescribed fires were conducted during a ~16-year period. These changes coincided with a shift in grass-dominated cover from 45% to 84% and a 33% reduction in overall vegetation height and density (Murphy and Smith 2007).

The increase in Sharp-tailed Grouse density on management units undergoing initial prescribed fire treatments in our case study was consistent with a 32% increase in total abundance of males at the landscape scale during the Landscape Fire period, when >50% of the refuge had been burned at least once. Historically, the fire return interval for the eastern, more mesic part of the NMGP that encompasses LNWR averaged roughly six years (Bragg 1995; Madden *et al.* 1999). A mosaic of management units under short (2–4 years) and moderate (5–7 years) fire return intervals seems optimal for most native grassland bird species at LNWR (Madden *et al.* 1999). The heterogenous structure and general composition of vegetation in units managed under these fire return intervals (Madden *et al.* 1999, 2000) may be ideal for Sharp-tailed Grouse as well. Indeed, the mean annual density of lekking males during the Initial Fire period was high on units treated by prescribed fire even though most units were burned two to three times with only 1–2 years between treatments. Although Sharp-tailed Grouse have a general affinity for frequent disturbance and early successional stages (Kirsch *et al.* 1973; Connelly *et al.* 1998), the consistently high mean annual densities of lekking males across MBs of all fire history categories (excluding MBs that also were intensively grazed; Figure 5b) during the Landscape Fire period, suggest that the bird's abundance in NMGP does not necessarily increase with increasing "fire experience" (*sensu* Madden *et al.* 1999), at least during 10- to 15-year periods.

Conclusions about effects of a given fire return interval on the structure and general composition of NMGP—and thus on attractiveness of the habitat for Sharp-tailed Grouse—should be considered tentative, particularly if other types of defoliation treatments are applied between prescribed fires. The type, frequency, duration, and intensity of any such treatments likely influence effects of a given fire return

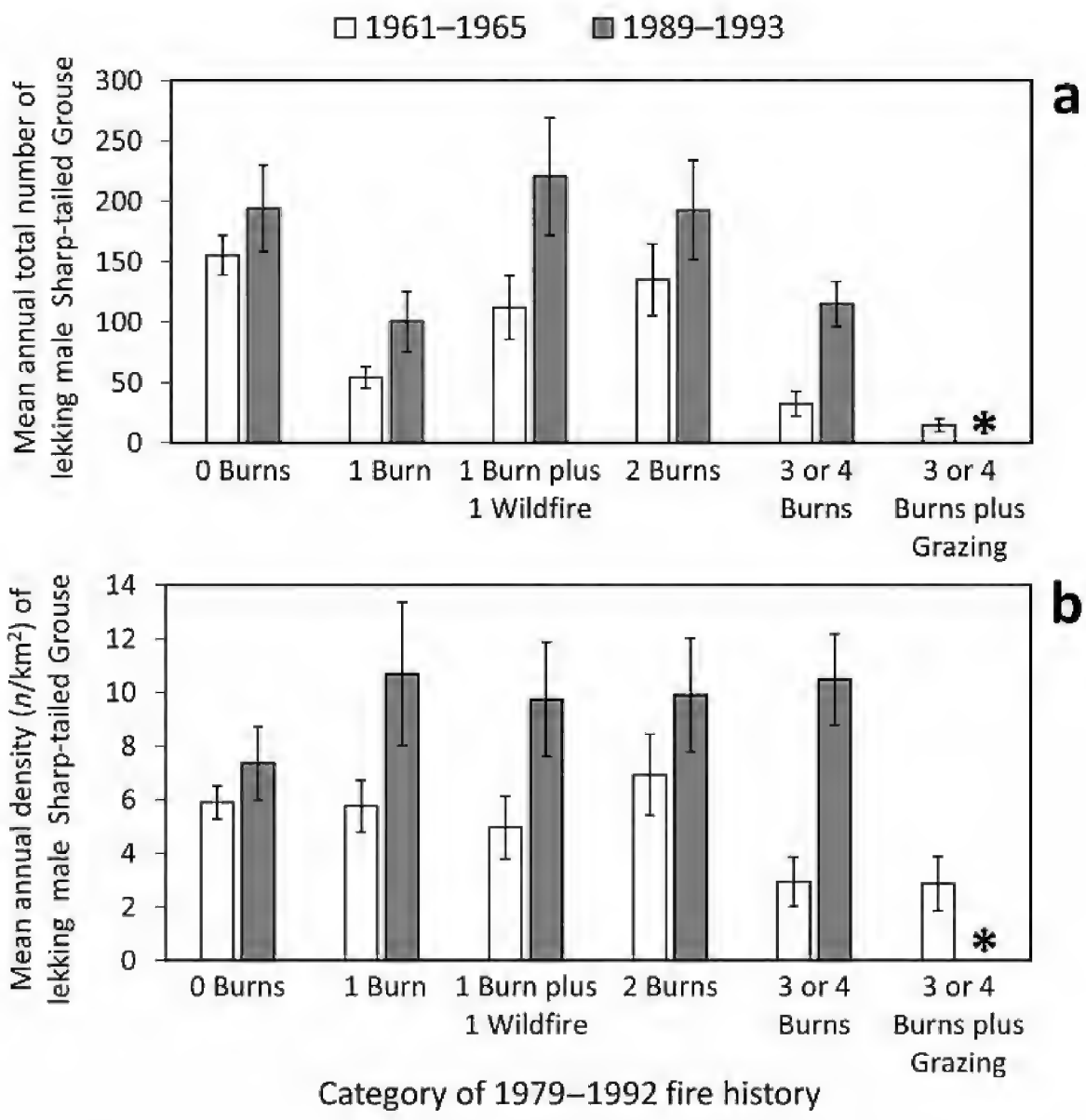

FIGURE 5. Mean annual abundance (i.e., total number of individuals, a) and density (i.e., number of individuals/km^2, b) of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) attending leks in spring at Lostwood National Wildlife Refuge, northwestern North Dakota: (1) during 1961–1965, amid ~60 years of fire suppression; and (2) during 1989–1993, by which time >50% of the refuge area had been prescribe-burned at least once, beginning in 1979. The refuge is divided into six categories of management blocks based on numbers of fires experienced during 1979–1992. Thus, values during 1961–1965 reflect abundance and density before fire was re-introduced to the refuge. Each category of fire history is represented by two to six management blocks except the "1 Burn plus 1 Wildfire" (1+W) category, which is represented by a single but very large (22.7 km^2) management block. Due to an artificially severe wildfire on this latter area in August 1988, the 1989 count of lekking males was replaced by like data from 1987, following the management block's first prescribed fire in 1986 (see text). In addition to having multiple prescribed fires, management blocks in the "3 or 4 Burns plus Grazing" (3+G) category received intensive, prolonged grazing by cattle in spring and early summer for 2–3 years during 1988–1992, leaving little residual nesting cover for Sharp-tailed Grouse in subsequent springs. Error bars are 90% CIs. Asterisks indicate no lekking males detected.

interval on prairie vegetation in general, e.g., by reducing fuel loads (Engle and Bidwell 2001). Also, influences of various fire return intervals on vegetation structure and composition may be confounded by the presence of Smooth Brome (*Bromus inermis* Leysser) and Kentucky Bluegrass (*Poa pratensis* L.), two introduced, cool-season grass species that have become pervasive in much of the NMGP (Romo *et al.* 1990; Murphy and Grant 2005). These grasses appear to be increasing regardless of prairie management treatment history (Ellis-Felege *et al.* 2013; but see Kobiela *et al.* 2017), a change that may reduce the availability and attractiveness of cover for Sharp-tailed Grouse.

Our comparisons of Sharp-tailed Grouse density and abundance among the Fire Exclusion, Initial Fire, and Landscape Fire periods included some basic components of a before-after-control-impact (BACI) study design, but our overall case study was observational in nature and lacked robust replication. Ideally, a statistically valid experimental design with replication across a more extensive landscape would be used to distinguish effects of habitat management on Sharp-tailed Grouse from confounding, non-management, factors, e.g., precipitation extremes. Aldridge *et al.* (2004) attempted this in an aspen parkland landscape. Regardless, long-term monitoring of Sharp-tailed Grouse abundance at LNWR enables passive

adaptive management of the species' NMGP habitat (Aldridge *et al.* 2004).

Acknowledgements

We dedicate this paper to the memory of three northern prairie and prairie grouse management experts: Michael Gratson, Leo Kirsch, and Arnie Kruse. During 1961–1965, counts of lekking male Sharp-tailed Grouse at Lostwood National Wildlife Refuge were conducted by Merrill Hammond, Ned Peabody, and Don White. Bob Danley and Ken Maruskie assisted us with lek counts during the 1990s. Discussions with Ryan Nielson (Eagle Environmental Inc.) enhanced our approach to data analyses. We thank Todd Grant, two anonymous reviewers, and Associate Editor Jenn Foote for many comments that markedly improved our manuscript. Findings and conclusions in this article are those of the authors and do not necessarily represent views of the United States Fish and Wildlife Service.

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Humpback Whale (*Megaptera novaeangliae*) observations in Laskeek Bay, western Hecate Strait, in spring and early summer, 1990–2018

Anthony J. Gaston[1,*], Neil G. Pilgrim[1], and Vivian Pattison[2]

[1]Laskeek Bay Conservation Society, P.O. Box 867, Queen Charlotte City, British Columbia V0T 1S0 Canada
[2]Department of Geography, University of Victoria, 3800 Finnerty Road, Victoria, British Columbia V8P 5C2 Canada
[*]Corresponding author: tonygastonconsult@gmail.com

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Abstract

We describe observations of Humpback Whales (*Megaptera novaeangliae*) made along the west side of central Hecate Strait, British Columbia, during the spring and summer of 1990–2018. From none in March, the frequency of sightings increased from early April to a peak in May, then fell in June with few in July. The frequency of sightings during the peak period (1 May–20 June) increased over the course of the study at a mean rate of 6% a year, similar to increases recorded elsewhere in British Columbian waters. The frequency of sightings was highest in years when the Oceanic Niño Index for January–March was low and peaked earlier in years when the Oceanic Niño Index was high. Both of these relationships suggest a connection between Humpback Whale sightings in western Hecate Strait and the larger oceanographic context, with sightings more frequent in years of lower water temperatures.

Key words: Humpback Whale; *Megaptera novaeangliae*; Hecate Strait; seasonal occurrence; population trends; oceanography

Introduction

Humpback Whale (*Megaptera novaeangliae*) is the most common rorqual along the west coast of Canada during the spring and summer, occurring in northern British Columbia (BC) waters principally from May to September (COSEWIC 2011; Ford 2014). Most of the population that occurs in summer in northern BC waters winters around the Hawaiian Islands (Calambokidis *et al.* 2001). Whales sighted in spring in BC waters may remain for the whole summer or may pass through *en route* to summering grounds farther north (Ashe *et al.* 2013; Ford 2014). Most Humpback Whales are believed to be faithful to their summering areas, with the same individuals identified in particular parts of the summer range over several years (Rambeau 2008; Gabriele *et al.* 2017).

Humpback Whale populations were heavily impacted by commercial whaling that took place along the BC coast between 1905 and 1967 (Trites *et al.* 2007). Since then, detailed observations between 1985 and 2014 in Glacier Bay, Alaska, showed that a humpback population summering there increased over that period at a mean 5% annually. A similar estimate, but based on fewer years, has been obtained for the population summering in inlets along the mainland coast of Hecate Strait (Ashe *et al.* 2013), while an assessment of trends in BC waters by COSEWIC (2011) suggested an annual rate of increase in adult numbers of 4%. These trends reflect a population recovery after severe reductions by commercial whaling in the period before 1970 (COSEWIC 2011).

Since 1990, the Laskeek Bay Conservation Society, a citizen science non-governmental organization based on the archipelago of Haida Gwaii, BC, has conducted observations of marine mammals in western Hecate Strait, in one of the three important Humpback Whale areas in BC waters identified by Dalla Rosa *et al.* (2012). Observations were made from a seasonal camp on East Limestone Island, a 40-ha island off the southeast corner of the much larger Louise Island, on the east coast of Haida Gwaii (Figure 1).

In this paper, we summarize observations of Humpback Whales made over the period 1990–2018 from March to July. We analyze seasonal and inter-annual variation and compare our observations with those made elsewhere in the northeast Pacific. Given the large amount of inter-annual variation in our data, we compare them with variations in oceanographic

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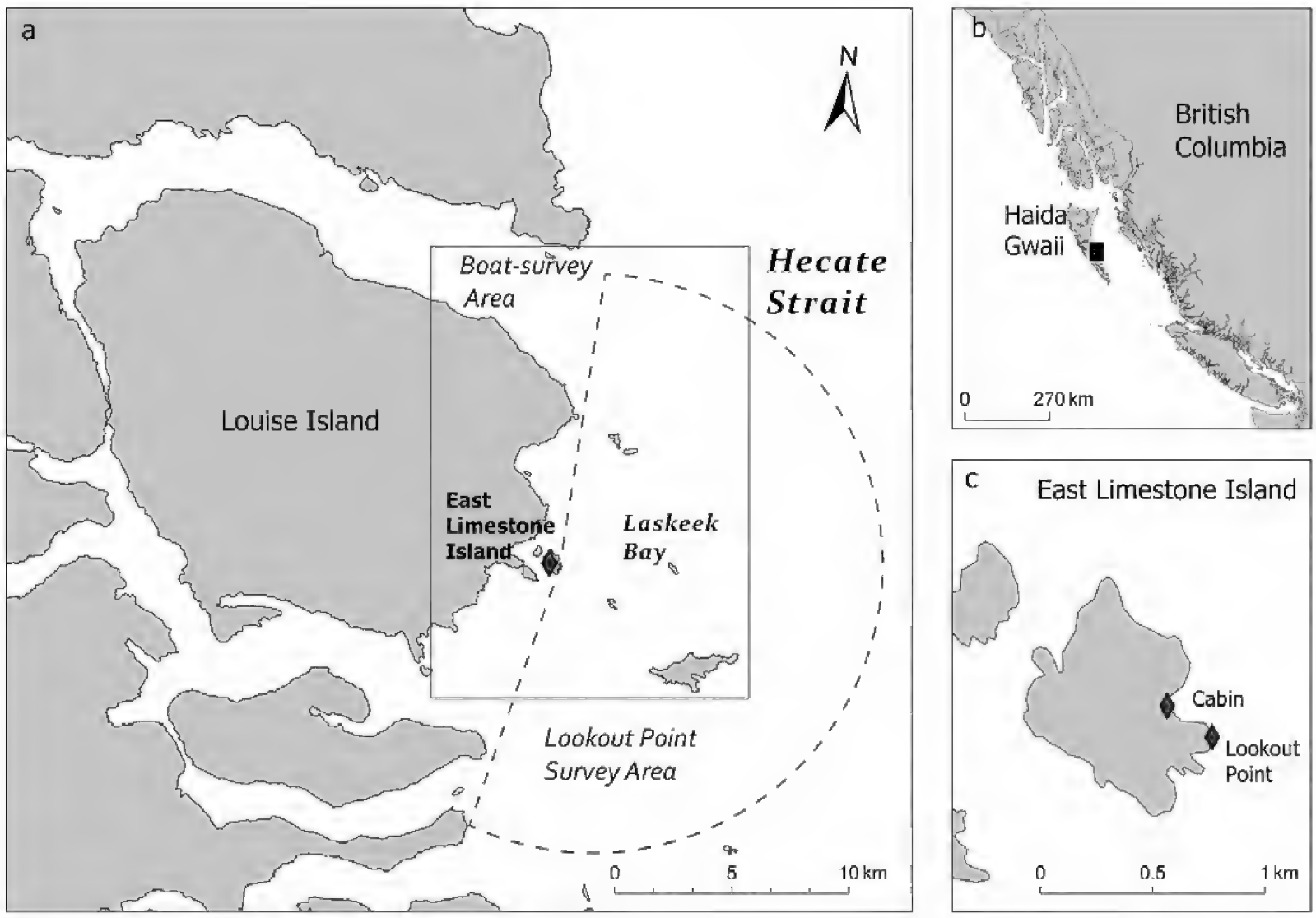

FIGURE 1. Map of the study area showing: a. the arc of view from Lookout Point (dashed line) and the area within which boat surveys were conducted regularly (rectangle); b. the location of Haida Gwaii; c. detail of East Limestone Island.

conditions, both in the northeast Pacific and more locally in BC waters, to improve our understanding of the factors influencing Humpback Whale occurrence in western Hecate Strait.

Methods

Fieldwork

The Laskeek Bay Conservation Society camp on East Limestone Island (Figure 1a–c) has been active in spring and early summer since 1990. Marine mammals were noted both systematically and incidentally throughout the period when camp was occupied, for periods between 56 and 126 days (mean 88 days/year). Starting dates varied from 15 March to 5 May. In 1990, the first year of operations, camp was open 25 April–5 June, but thereafter, in all years up to 2004, camp opened before 10 April and closed between 3 and 25 July. From 2005 to 2018, camp opened later, with starting dates between 21 April and 5 May and closure between 8 and 22 July (Table 1).

Systematic timed observations of marine mammals were made for several hours each week from a point ~20 m above sea level (asl; maximum tidal range 4 m; Fisheries and Oceans Canada 2019) at the southeastern tip of the island. If two or three observers were present, they watched together for 30 or 60 min, continuously, scanning waters within sight (an area of ~120 km^2 shown approximately in Figure 1a). When marine mammals were sighted, they were observed through a 25×60 spotting scope. Single observers scanned the area by dividing it into three sectors and spent 10 min on each sector in rotation. Watches were conducted during good visibility (usually >15 km), with sea conditions reflecting a Beaufort sea state of 3 or less (defined by World Meteorological Office as waves <1.25 m; National Oceans and Atmosphere Administration 2002).

Incidental observations were made from several locations. The camp is located on the east shore of the island (Figure 1c), from which an arc of ~120° is visible in an east-northeast direction. Most observations from camp were made from the cabin, ~5 m asl. People were present in camp for several hours each day. Incidental observations were made from other parts of the island shores and additional observations were also made from a small boat, used to survey for marine birds for 6–8 h every 10–15 days (area of rectangle in Figure 1a), as well as while travelling between islands for other fieldwork.

Analysis

To investigate seasonal variation in whale num-

TABLE 1. Period during which the East Limestone Island camp was active in each year of the study.

Year	Start date	End date	Days of observation
1990	25 April	19 June	56
1991	26 March	14 June	81
1992	9 April	3 July	86
1993	9 April	10 July	98
1994	5 April	15 July	102
1995	25 March	15 July	113
1996	20 March	11 July	114
1997	15 March	11 July	119
1998	3 April	9 July	98
1999	2 April	25 July	115
2000	1 April	20 July	111
2001	22 March	25 July	126
2002	20 March	7 July	102
2003	20 March	4 July	99
2004	30 April	22 July	84
2005	22 April	22 July	92
2006	28 April	20 July	84
2007	28 April	13 July	77
2008	5 May	16 July	73
2009	1 May	14 July	75
2010	1 May	9 July	70
2011	29 April	9 July	71
2012	4 May	12 July	70
2013	3 May	12 July	71
2014	1 May	11 July	72
2015	1 May	10 July	71
2016	30 April	22 July	84
2017	4 May	22 July	80
2018	4 May	20 July	78

bers, we used three statistics: (a) the proportion of observation days on which whales were seen, (b) the monthly sums of the number of whales seen each day (whales × days), and (c) the average number of whales seen on days when at least one was recorded. We included all years in this analysis, although no observations were made in July 1990 and 1991 and, after 2003, no observations were made before 21 April. Because of variation in observing dates each year, only records from the 50-day period 1 May–20 June were used for inter-year trend analysis. Observations were made daily in every year during this period. We used the proportion of days on which one or more whales were seen during this 50-day period as our index of whale frequency (whale index, WI) for time-trend analysis.

To examine the possible influence of large-scale oceanographic variation on the occurrence of Humpback Whales in Laskeek Bay, we corrected the number of whales observed assuming an increasing population trend of 4% annually, as suggested by COSEWIC (2011). The resulting adjusted index of whale abundance is referred to as the "corrected whale index" (CWI):

$$\mathrm{CWI} = (D_w / D_t) \times 1.04^{(2018 - y)}$$

where D_w = days on which whales were sighted in a given year; D_t = total days camp was occupied during 1 May–20 June; and y = year of observations.

This index was compared with the following ocean climate indices:

As a measure of the El Niño/Southern Oscillation (ENSO), the Oceanic Niño Index (ONI) for January–March, the three-month running mean of ERSST. v5 (extended reconstructed sea surface temperature anomalies in the Niño 3.4 region; 5°N–5°S, 120–170°W), based on centred 30-year base periods updated every five years (National Weather Service n.d.). Sea surface temperatures in the northeast Pacific tend to be closely correlated with indices of the ENSO cycle (e.g., Niño 3.4 index; Tseng *et al.* 2017).

As a measure of the Pacific Decadal Oscillation (PDO), the H300-based PDO index (HPDO), defined as the projections of monthly mean H300 anomalies from the National Centers for Environmental Prediction's Global Ocean Data Assimilation System onto their first empirical orthogonal function vector in the North Pacific (20°–60°N), based on the 30-year period from 1981 to 2010 (GODAS n.d.).

Years in which the ONI was −0.5 or lower for the first three months of the year were classified as "cold" (as defined at National Weather Service n.d.) and the CWI for these years was compared with the CWI for warmer years. Comparisons among days with and without whale sightings were made using the Fisher exact probability test. Tests for time trends were made using linear regression and the Pearson correlation coefficient. Statistics were performed using Statistica v. 7.1 (Statsoft, Inc., Tulsa, Oklahoma, USA). Mean values are given ± 1 SE.

Results

Humpback Whales were seen in all but three years of the study, with sightings from early April to late July. They were recorded on 14% of the 2572 days that camp was occupied and on 20% of the 1673 days during the period 1 May–20 June. No humpbacks were seen in March and the frequency of sightings built up during April, with the buildup continuing longer in cold than in warmer years (Figure 2). The highest sighting frequency occurred in May, peaking 21–31 May in cold years (when whales were seen on 36% of days) and 1–10 May in other years (recorded on 21% of days). WIs were significantly higher in cold years than in others during 21–31 May and 1–10 June (Fisher exact test, $P < 0.001$ for both periods).

No humpbacks were seen in 1990, 1991, or 1996. The highest frequencies for 1 May–20 June occurred in 2007 (WI = 56% of days), 2008 (63%),

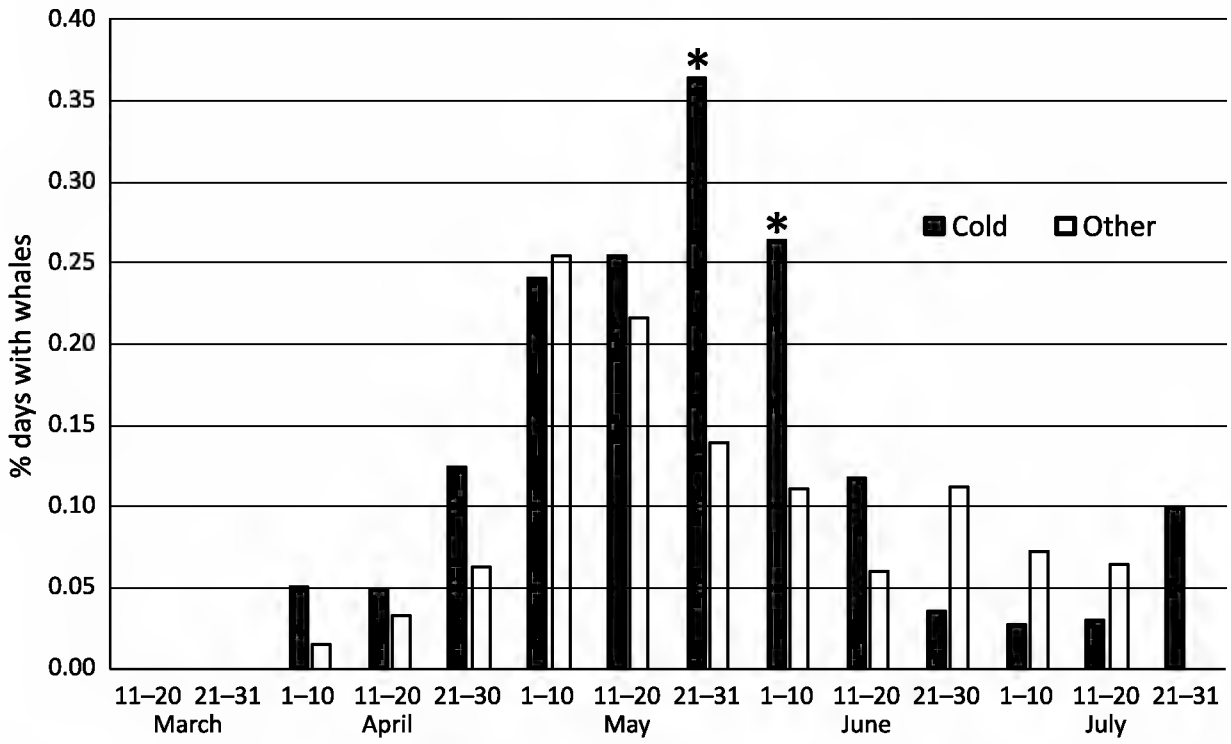

FIGURE 2. Proportion of days when Humpback Whales (*Megaptera novaeangliae*) were seen in Laskeek Bay in relation to date, for years when the Oceanic Niño Index was less than −0.5 during January–March (cold) and other years (1990–2018). *Proportion of days with whales was significantly greater in cold years than in other years (Fisher exact $P < 0.001$).

2016 (39%), and 2018 (41%). Six of the 10 lowest years occurred before 1999 (Figure 3). There was a significant positive correlation between year and the proportion of days with whales during 1 May–20 June ($r_{27} = 0.48$, $P = 0.009$). A similar positive correlation was found for non-cold years ($r_{17} = 0.48$, $P = 0.04$) when analyzed separately. The correlation coefficient was similar, but non-significant for cold years ($r_8 = 0.41$, $P = 0.24$). The linear regression slope for the proportion of days with whales over time was consistent with an annual rate of increase of 6%. Slopes were similar for cold and non-cold years when analyzed separately, but were closer to a 4% rate of annual increase (Figure 4).

Number of whales per day

Summing daily counts, 1750 humpback sightings were recorded, 1602 during the period 1 May–20 June. Probably many of these involved the same animals on different days, but we think it unlikely that many involved the same animal seen more than once on a given day. The highest number was recorded during May (1304, 75% of all sightings). Highest numbers of whales × days were recorded in 2003 (142), 2007 (213), and 2014 (233). The number sighted on days when at least one whale was seen aver-

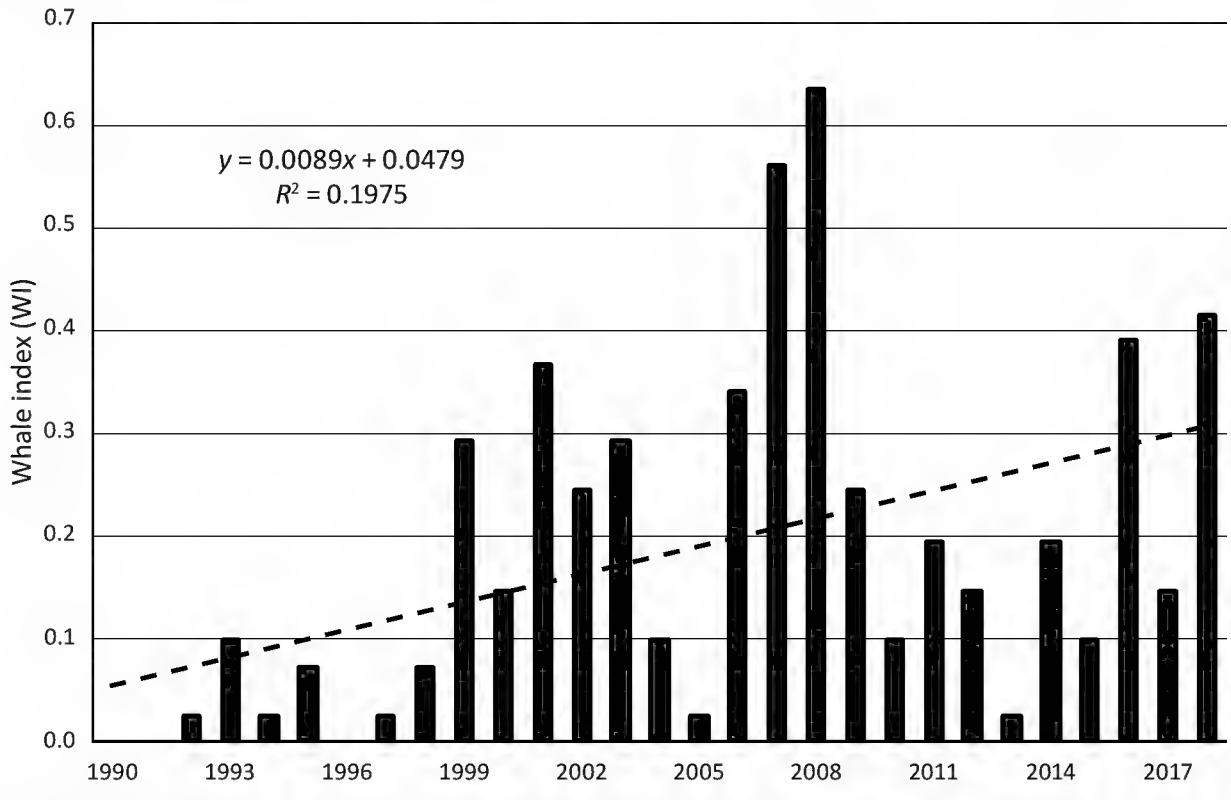

FIGURE 3. Whale index (WI), i.e., days when Humpback Whales (*Megaptera novaeangliae*) were seen in Laskeek Bay (11 May–20 June) as a proportion of all days, during 1990–2018, showing linear regression.

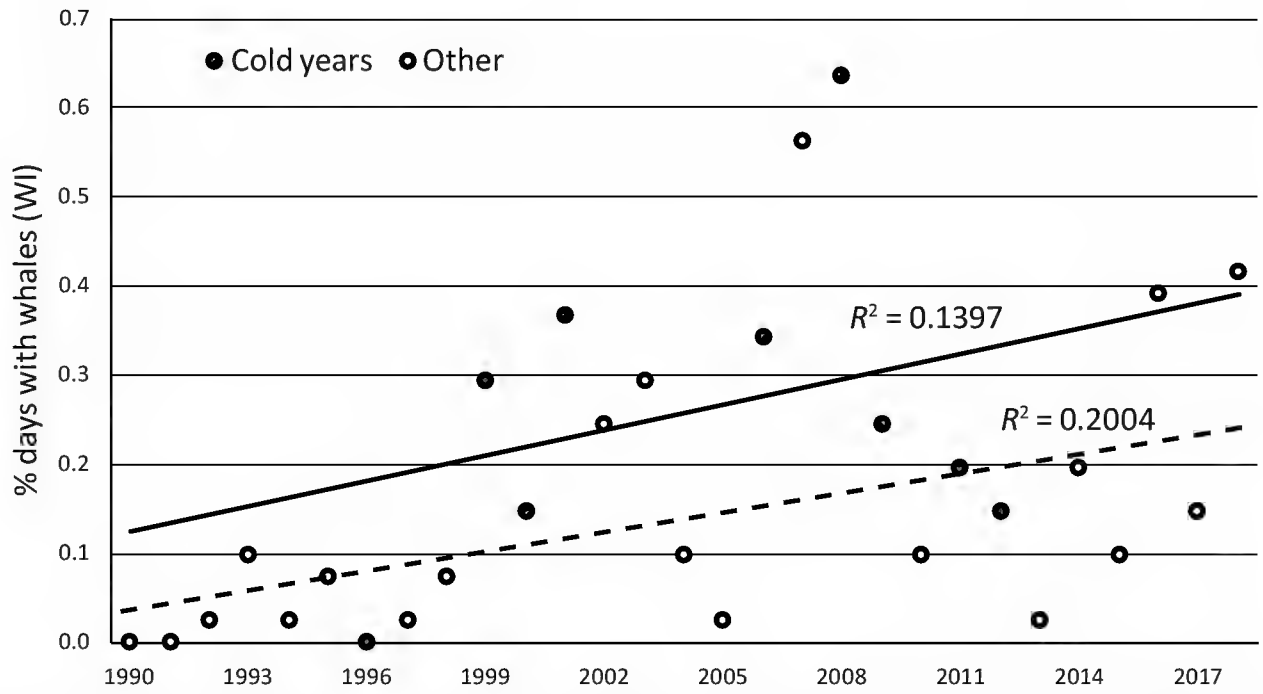

FIGURE 4. Proportion of days with whales (WI) in Laskeek Bay (11 May–20 June) separated into years with Oceanic Niño Index below −0.5 during January–March (cold years) and warmer years (other).

aged 5.6 whales/day during 1 May–20 June and 2.3 whales/day outside that period (Figure 5). The number of whales seen per day on days when at least one whale was seen did not differ significantly between cold years (4.5 ± 1.8 whales/day) and other years (4.3 ± 0.9 whales/day, $t_{24} = 0.11$, $P = 0.9$).

Effects of oceanography

The proportion of days with whales was generally higher in years with negative ONI (cold years, 28% ± 5%) than others (15% ± 4%, $t_{28} = 2.02$, $P = 0.05$). CWI was negatively correlated with ONI for January–March ($r_{27} = 0.37$, $P = 0.037$; Figure 6), but did not show any relation to the HPDO index ($P > 0.10$). The ONI accounted for 17% of variation in CWI ($F_{1,27} = 4.82$, adjusted $R^2 = 0.17$, beta = −0.41).

Discussion

Despite substantial variation in the amount of effort devoted to whale observations and the inevitable fluctuations in viewing conditions created by weather, our results show a clear increasing trend in the frequency of Humpback Whale sightings in Laskeek Bay since 1990. The complete set of annual indices has a regression coefficient consistent with a 6% annual rate of increase, while dividing the years into those displaying colder relative oceanic conditions and others (average or warmer conditions), based on the ONI, suggests a rate of increase closer to 4% for both samples. Observations of marine mammals from nearby Reef Island (5 km ESE of East Limestone Island) during April–June of 1984–1989

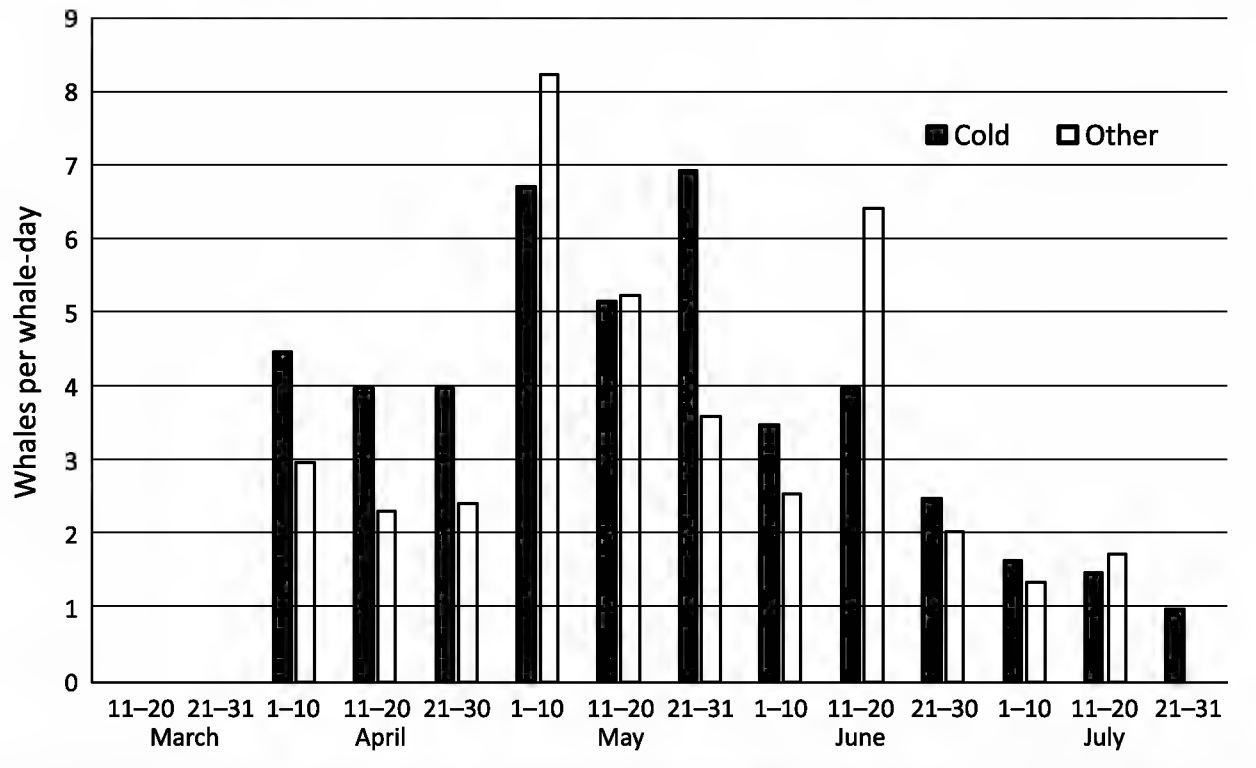

FIGURE 5. Number of whales seen per day in Laskeek Bay (11 May–20 June) on days when at least one was recorded (1990–2018).

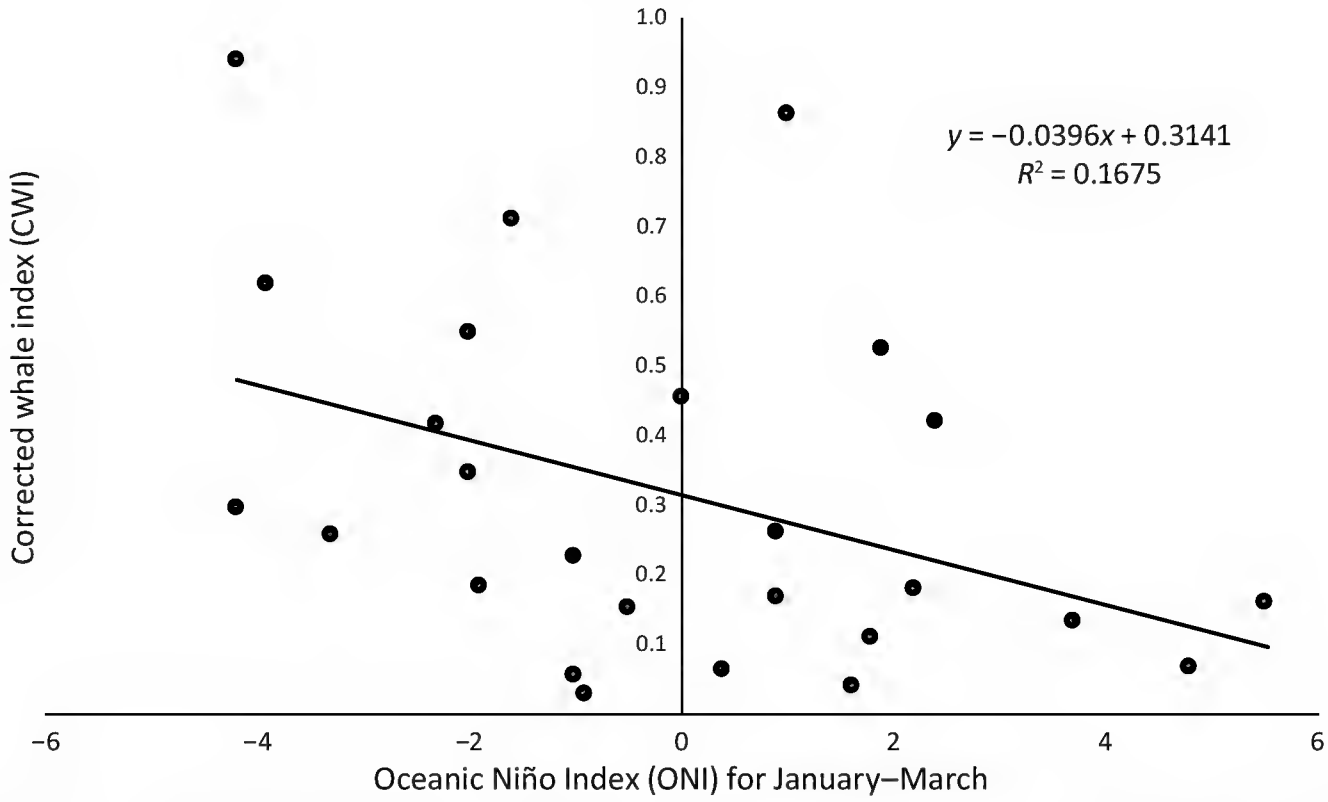

FIGURE 6. The corrected whale index (assumes a 4% annual rate of population increase) compared with El Niño/Southern Oscillation conditions, represented by the Oceanic Niño Index (ONI). Negative ONI is associated with colder than average ocean conditions, while positive ONI is associated with warmer than average conditions (Laskeek Bay, 1990–2018).

included sightings of Humpback Whales only in 1985 (up to three on 17 days), 1987 (one on a single day), and 1989 (up to five on six days; Gaston and Jones 1991). In all years, these observations extended from early April to mid-June, but all sightings fell between 2 May and 6 June (Gaston and Jones 1991). The paucity of sightings during the 1980s supports the idea that numbers have increased substantially since then. Our results are consistent with those obtained elsewhere in BC waters (COSEWIC 2011; Ashe *et al.* 2013). An estimate by Fisheries and Oceans Canada (2009) suggested a mean rate of increase for the BC population of 4.1% a year, identical with ours once warm and cold years are separated. The appearance of large numbers of Humpback Whales in Queen Charlotte Strait and the inside passage off Vancouver Island since the early 2000s (Nichol *et al.* 2017) is also consistent with our findings.

The absence of humpbacks in March and low numbers in the first 20 days of April may be partly accounted for by lower population size in the early years of the study, when most observations in March and April occurred. However, the number of days of observations after 10 July was biased toward recent years; thus, the decrease in number of sightings after mid-June is unlikely to have been influenced by the population trend.

Some of the humpbacks recorded in Laskeek Bay may be migrating to summering areas farther north. The timing of peak numbers reported in Laskeek Bay fits well with data from Glacier Bay, Alaska, ~750 km by sea to the north of Laskeek Bay, where the peak arrival of humpbacks occurs in June (Gabriele *et al.* 2017), about three weeks after the peak in Laskeek Bay. This rate of travel (about 36 km/day) is comfortably within the migration speed of 48 km/day observed for humpbacks by satellite telemetry (Lagerquist *et al.* 2008). However, it is possible that some or all of the whales seen in Laskeek Bay shift to other BC waters in July. Animals were frequently observed feeding in Laskeek Bay, both lunging at the surface and "flick feeding" (A.J.G. unpubl. data), which Ford (2014) mentions as common in waters off Moresby Island. It seems likely that most whales observed were feeding in the vicinity, causing them to pause in the area for a period.

Inter-year variability in sighting frequency was high, with the proportion of days with humpback sightings during the period 1 May–20 June, varying from 0 to 60%. Part of this variation can be explained by oceanographic processes, with the Oceanic Niño Index accounting for 17% of variation in the trend-corrected proportion of whale sightings. Seasonal trends in sightings, with sightings in cold years peaking later than those in other years, suggests that ocean conditions, influenced by large-scale processes, such as ENSO, may affect the suitability of inshore waters along the western side of Hecate Strait for humpback foraging. A similar effect of large-scale oceanographic forcing on Humpback Whales (in that case on diet) was reported by Fleming *et al.* (2016). The fact that numbers seen on a given day were not affected by ONI suggests that much of the variation in observation frequency probably relates to the rate at which the whales pass through the area, rather than being accounted for by fluctuations in the number of indi-

viduals using the area. Given the much greater frequency of whale sightings in Laskeek Bay in recent years, we may be able to make more detailed observations in future, perhaps with greater emphasis on photo-identification, giving us better understanding of the importance of Laskeek Bay waters to individual Humpback Whales.

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A Tribute to Rudolph Frank Stocek, 1937–2018

Donald F. McAlpine[1,*] and Graham J. Forbes[2]

[1]New Brunswick Museum, 227 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[2]University of New Brunswick, Fredericton, New Brunswick E3B 5A3 Canada
[*]Corresponding author: email: donald.mcalpine@nbm-mnb.ca

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Rudolph (Rudy) Frank Stocek, aged 81, "the eagle man" of New Brunswick (Figure 1), passed away on 2 December 2018 at the Dr. Everett Chalmers Hospital, Fredericton, New Brunswick following a stroke. Rudy was born 5 June 1937 in Woodside, New York, just south of the Bronx, even then one of the most densely populated regions of the United States. However, summers at his grandparent's farm in Millhurst, New Jersey, left Rudy with a deep love of the outdoors and a fascination with the natural history of the trees, fish, birds, and other wildlife that populated the surrounding waterways and woodlands.

The north woods beckoned, and Rudy set off to the University of Maine at Orono, graduating in 1959 with a B.Sc. in Wildlife Management and a minor in Forestry. During his undergraduate summers he worked for the Maine Department of Inland Fisheries and Game, undertaking stream and lake surveys, tagging fish, and reading fish scales. Athletic and active, Rudy played football and boxed in university. His athleticism would serve him well as both a field biologist and an instructor in wildlife management.

With a solid, practical, introduction to fisheries management during his summers, it probably seemed natural to pursue fisheries science at the Ontario Agricultural College in Guelph, Ontario, then affiliated with the University of Toronto. Rudy completed his M.Sc. in 1962 under the supervision of Dr. Hugh R. McCrimmon, a committed fish culturist, now remembered for his volume on carp in Canada (McCrimmon 1968). Although Rudy later became best known for his work on raptors, his interest in freshwater fish never left him. He designed and taught the first ichthyology course offered at the University of New Brunswick, and he reported the addition of Muskellunge (*Esox masquinogy*) to the Saint John River system. Even as he approached 70, he documented the occurrence of Fat Head Minnow (*Pimephales promelas*) in New Brunswick.

Figure 1. Rudy Frank Stocek, 1937–2018. Photograph taken as part of a composite for the 1997 Maritime Forest Ranger School graduating class. Photo: J. Cummings.

Brief stints as a wildlife biologist with the Metropolitan Toronto and Region Conservation Authority (1960–1961), and as Manager of the Tinicum Wildlife Preserve, Philadelphia (1961–1965), followed his M.Sc. In 1965 Rudy entered a Ph.D. program at the University of Western Ontario to study growth and development in young Canada Geese (*Branta canadensis*). However, his marriage in 1960 (to Arlene, *nee* Wellhauser), and the two children that followed (Rudy Jr. born 1963, Lehanne born 1964), made a 1968 job opportunity in New Brunswick simply

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too good to pass up. Rudy and family moved east to the Maritimes, where Rudy took a position as an Instructor and Fish and Wildlife Biologist with the Maritime Forest Ranger School (MFRS; since 2003 the Maritime College of Forest Technology). Opened in 1946 as a co-operative venture of the New Brunswick–Nova Scotia governments and the forest industry, at its establishment the role of the MFRS was to re-train and integrate returning World War II veterans. However, by the time Rudy arrived in New Brunswick, MFRS was catering to students from wide and varied backgrounds.

By 1973, Rudy's ability to inspire students interested in pursuing careers that required a knowledge of fish and wildlife biology had become evident. From then until his retirement in 2002, Rudy designed, directed, and with other instructors, delivered, the MFRS wildlife technology program as his "day job" to hundreds of young men and women intent on becoming forest rangers, wildlife protection officers, fish and wildlife technicians, park rangers, and wardens. But for one with Rudy's energy and curiosity, teaching alone was not enough. As an independent fish and wildlife biologist, he also accepted contracts from various federal and provincial government departments and private environmental consulting firms to investigate a variety of wildlife-related issues in the Maritimes. A 1982 contract from the New Brunswick Environmental Assessment Branch that identified and assessed more than 90 environmentally sensitive areas in southern New Brunswick was an important precursor to current work by government and land trusts now intent on setting aside habitat in New Brunswick for conservation purposes. In the broader context, and in a province dominated by industrial forestry, Rudy's research and teaching can be seen as part of a rising tide of concern for North American wildlife and the environment that became evident in the 1970s. Until 1968, New Brunswick was one of the heaviest DDT (Dichlorodiphenyltrichloroethane) users in North America, a pesticide identified as a major cause of raptor declines across the continent and one that appears to have had impacts on aquatic ecosystems in the province that are still evident (Kurek *et al.* 2019).

With the establishment of the *New Brunswick Endangered Species Act* in 1976 (superseded by the *New Brunswick Species at Risk Act* in 2012) a short list of species was accorded protection. Although Bald Eagle (*Haliaeetus leucocephalus*) was assigned regionally endangered status, there were limited data to work from.

There are two sources of Bald Eagles occupying New Brunswick. A resident population breeds in the province (*Haliaeetus leucocephalus washingtoniensis*), while immature birds fledged in the southeastern United States (*Haliaeetus leucocephalus leucocephalus*) disperse northward into New Brunswick in the late summer. In the early 1970s the impact of pesticide use in the United States was evident in New Brunswick, with a reduced number of southern birds available to disperse northward. Although legendary New Brunswick wildlife biologist Bruce Wright (1912–1975) had identified the Saint John River estuary as critical summer habitat for Bald Eagles fledged south of the province (Wright 1953), historically the species was never a common breeding bird in New Brunswick. A mere 12–15 pairs nested in the province by the early 1970s.

Accordingly, Rudy was contracted by the New Brunswick Department of Natural Resources to undertake regular Bald Eagle surveys in New Brunswick. This was not Rudy's first foray into raptor research. In 1973 Rudy had been engaged by the Canadian Wildlife Service to assess the status and reproductive success of Peregrine Falcon (*Falco peregrinus)* and Osprey (*Pandion haliaetus*), along with Bald Eagle, across the Maritimes. Rudy would continue annual New Brunswick Bald Eagle surveys for the next 25 years. When funds for aerial surveys became difficult to secure, undeterred, Rudy was able to take advantage of members of the Fredericton Flying Club and the 422nd Tactical Helicopter Squadron out of Canadian Forces Base Gagetown. In addition to determining numbers of breeding pairs in New Brunswick, Rudy also collected information on distribution, nesting success, habitat requirements, and winter feeding patterns and developed management guidelines for individual Bald Eagle nesting sites (Figure 2).

With a growing interest in the problems of raptor conservation in North America, Rudy soon found himself presenting his findings, both for Bald Eagles and Ospreys, at meetings of raptor specialists across North America. As an experienced educator and an engaging speaker, Rudy also lectured widely on Bald Eagle in the Maritimes to regional audiences. For the media, he became the go-to-guy for expert opinion on a bird with a high public profile, and huge significance to the Indigenous community. Rudy went on to write the Bald Eagle account for the iconic federal government Hinterland Who's Who series (Stocek 1992) and in 2006 summarized his decades of research on the bird in a book that ultimately received an independent publishers book award.

While best known for his work on raptors, Bald Eagles in particular, Rudy also found time to work and publish on other Maritime wildlife, including Common Loon (*Gavia immer*), the elusive Cougar (*Felis concolor*), and Tree Swallows (*Tachycineta bi-*

FIGURE 2. Rudy banding a Bald Eagle (*Haliaeetus leucocephalus*) nestling in southwestern New Brunswick, *circa* 1978. Photo: unknown.

color). A useful and well-received field guide to New Brunswick trees and shrubs in winter helped fulfil his commitment to teaching, but was also made available to a wider general audience (Figure 3). A mainstay of provincial government committees dealing with species of conservation concern, in 1995 Rudy received the Career Achievement Award of the Atlantic Society of Fish and Wildlife Biologists and in 2010 an Award of Professional Excellence from the University of Maine Wildlife Program. Outgoing and gregarious, Rudy somehow still found time to play tuba and accordion in five local bands, stay active as a judge and organizer for the New Brunswick and Canadian gymnastics communities (including judging at the 1976 Olympics in Montreal), and help manage the local curling club!

Today, as the biodiversity crisis deepens, there is a growing chorus calling for the revitalization of natural history (Schmidly 2005; Nature News 2014; Tewksbury *et al.* 2014). In the best possible way, Rudy was an "old school" wildlife biologist who never left natural history behind, even as he upped his game after graduate school with courses in computer programming, teaching and administration, and media communications. A first-rate field naturalist, Rudy could identify trees and shrubs, and knew his fish, his birds, and his mammals. But his second love, after Arlene, his wife of 58 years, was the Bald Eagle. Although recent research has documented precipitous declines in numbers of birds of many species in North America (Rosenberg *et al.* 2019), Rudy had the satisfaction of watching New Brunswick's Bald Eagle populations, both migratory and resident, recover and rise dramatically, and know that his work played a role in this. By the time the 1986–1990

FIGURE 3. Rudy with a Maritime Forest Ranger School dendrology class in 2000, two years before his retirement. His 1991 winter field guide to trees and shrubs continues to be used in wildlife and forestry programs. Photo: Maritime School of Forest Technology.

Maritimes Breeding Bird Atlas had been completed, 40 pairs of Bald Eagles were confirmed nesting in New Brunswick (Erskine 1992), and numbers have continued to rise. An astounding 92 pairs of Bald Eagles nested in New Brunswick during the second atlas period (2006–2010; Stewart *et al.* 2015). Bald Eagle populations in New Brunswick are now recognized as secure. There have been few success stories for North American wildlife since Europeans arrived on the continent over 400 years ago, but the recovery of the Bald Eagle is one of them. That recovery is testament to the vision and the hard work of many, Rudy among them.

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Book Reviews

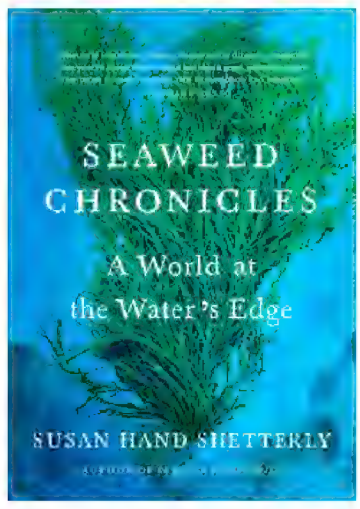
Book Review Editor's Note: *The Canadian Field Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes: CAD Canadian Dollars, USD United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pounds.

Botany

Seaweed Chronicles

By Susan Hand Shetterly. 2018. Algonquin Books of Chapel Hill. 271 pages, 27.59 CAD, Cloth.



Seaweed Chronicles is a blend of engaging popular science and interview-based narrative. It is highly place-based—the Gulf of Maine and surrounding area is the main geographic focus—but the nature of the subject matter means that connections are made between ocean coasts of all kinds. Shetterly has been involved in the regulatory and research communities for decades, and although her knowledge of the subject matter is apparent and the book is clearly well researched, this is not a treatise on the biology of seaweed. Several species of seaweed and the creatures that depend on them are highlighted and sufficient background is provided to inform the uninitiated, but this is primarily a book of stories, lives lived in a relationship with algae.

Each chapter focusses on one or a few related subjects, typically presented from the experience of a topic specialist via direct quotes and background information. The writing is usually conversational in tone and covers integrated topics such as the cod fishery collapse, island sheep farming, potato gardening, invasive species, and eider ducks. I started reading this book while living in landlocked Ontario, but after living on the East Coast for a month, I found it significantly more engrossing. That is not to say that those without a coastal context will not enjoy *Seaweed Chronicles*, but I suspect having at least casual contact with the ocean will only improve the reading experience. Shetterly does provide a short primer in the front matter on the algal species that feature prominently, but it would benefit from a measure of visual context—if you don't know the species in question, it may help to start your reading with a quick Internet image search. While the author does refer to specific facts and findings, the book itself does not contain references.

What *Seaweed Chronicles* does exceptionally well is tell the stories of individual people. Perspectives represented include those of researchers, farmers, harvesters, policymakers, and conservationists, and their lived experiences are the foundation of the book's content and structure. In this relatively short work, Shetterly delves into more dimensions of seaweed than you ever knew existed—as habitat, foodstuffs, artisanal martini decoration, animal forage, restoration tool, fertilizer, and so on. Some stories will probably grip you more than others depending on your personal context, but the writing is accessible and there is almost certainly something within that will pique your interest. For those with a coastal upbringing or fond place-based memories, *Seaweed Chronicles* provides an enjoyable stroll along the water with a good teacher to reveal new layers of understanding. For those less familiar, it offers a window into a macroalgae world that is foundational to the health of our oceans. Either way, it is worth the read.

Heather A. Cray
Halifax, NS, Canada

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ORNITHOLOGY

Birds of Saskatchewan

Edited by Alan R. Smith, C. Stuart Houston, and J. Frank Roy. 2019. Nature Saskatchewan. 765 pages, 79.95 CAD, Cloth.

For over three-quarters of a century, Nature Saskatchewan (formerly the Saskatchewan Natural History Society) has promoted investigation of the natural history of the province and surrounding areas by both amateurs and professionals. Many of the results have appeared in the quarterly *Blue Jay*, and in the Society's many Special Publications. Birds have been the focus of much of this work. *Birds of Saskatchewan* is the culmination of these efforts. It began as the dream of the late Manley Callin (1911–1985). His bequest helped fund its production and his dream is fulfilled by more than a decade of effort by the three editors, 107 authors of one or more species accounts, 69 photographers, and 24 reviewers.

Readers will find much of interest and value on every page of this large book (30 × 23 cm; 3 kg). The 437 accounts cover all species occurring regularly in the province, plus extinct, accidental, and hypothetical species. There is much more than just species accounts in this book. The first section is an "Introduction to the Province". It begins with a presentation of the seven "Natural Vegetation Zones in Saskatchewan", describing their natural flora and listing their typical and special bird species. One or more beautiful photos illustrate each zone and give lie to the common belief that the province has nothing but flat wheat fields. "Human History and the Flora and Fauna of Saskatchewan" reviews the influence of humans on the plants and animals, especially since the beginning of European settlement in 1872. It describes the negative impacts of human activity such as agriculture and resource extraction on many avian species, and the positive effects on species that have invaded or prospered in response to such activity. Efforts to protect and sustain bird populations are described, from the establishment of the first bird sanctuary in North America at Last Mountain Lake in 1887 to recent concerns about the federal government's divestiture of the Prairie Farm Rehabilitation Administration pastures and its impact on populations of threatened grassland bird species. "The Ornithological History of Saskatchewan" begins with Henry Kelsey's 1690 observation of Passenger Pigeons and Sir John Richardson's ornithological collections in 1827. A "who's who" of professional ornithologists (John Macoun, A.C. Bent, Francis Harper, W.E. Clyde Todd, George M. Sutton, W. Earl Godfrey, and J. Dewey Soper, among others) visited the province between 1880 and 1947. Their specimens are found in many of the major museums in North America. The roles of resident naturalists, bird banders, and institutions and organizations such as the Royal Saskatchewan Museum and Nature Saskatchewan are reviewed briefly. The section ends with a description of a century of "citizen science" which has contributed greatly to this book through Christmas Bird Counts (CBC), the Prairie Nest Records Scheme (PNRS), Breeding Bird Surveys (BBS), and through recent electronic activities such as Saskbirds (https://twitter.com/hashtag/saskbirds) and eBird (https://ebird.org/home).

Accounts for species that occur regularly in the province are about four pages in length, and packed with information. Each begins with a brief introduction to the species and a description of the North American range. A small map of the province is colour-coded to indicate seasonal distribution. "History" summarizes records prior to extensive settlement (1924). "Status" reviews relative abundance and population trends based on BBS data and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designation, where appropriate. Sections on "Spring", "Breeding", "Fall", and "Winter" summarize information on migration dates and breeding records. The final sections describe "Saskatchewan Research" and "Banding" (including names of banders with the number banded and recoveries). One to five photos showing plumages, nests, young, and, in many cases, behaviour, illustrate each account. Accounts for permanent residents and winter visitors include a table summarizing CBCs for different vegetation zones. Accounts for common waterfowl species include maps illustrating the recoveries of birds banded in the province, clearly demonstrating the role of Saskatchewan as the "duck factory" of North America. Accounts for accidental (44) and hypothetical (42) species are a half-page or less in length. They summarize records for accidentals and available evidence for species whose occurrence in

Saskatchewan has not been documented with photographs or sound recordings.

Most of the accounts include a shaded "Interest Box". Some provide special information (e.g., a short biography of Bernard Rogan Ross, for whom Ross's Goose and Gull were named) or give taxonomic information (e.g., the convoluted history of the scientific name for the Olive-sided Flycatcher). However, most recount specific experiences that contributors have had with the species in question. The late L.B. Potter describes (in the 1922 volume of *The Canadian Field-Naturalist*) the abundance of Sage-grouse in southwestern Saskatchewan in the first decades of the 20th century. He notes a tameness which led them to trespass into the garden and eat the lettuce plants. Editor Alan Smith remembers a night in the 1960s that he spent sleeping on the prairie wool at the Matador Field Station, only to be woken in the early morning by a Vesper Sparrow who landed on his hip and used him as a song perch. Such vignettes capture the pleasures, rewards, and memories that we all derive from our activities in the natural world.

Special mention must also be made of the photographs that grace almost every page of this book. Many of these are nothing short of spectacular—it would be impossible to select a favourite! The Bohemian Waxwing on the cover is a good example. The photographers and the Photo Selection Committee deserve congratulations for their efforts.

Eight appendices follow the species accounts and cover various topics, including a list of bird banders mentioned in the accounts, a summary of results of CBCs from 1913 to 2016, a map of BBS localities (none in the northern third of the province), and a useful gazetteer of place names mentioned in the accounts. Appendix B includes biographical sketches of 168 now-deceased individuals who contributed to our knowledge of Saskatchewan ornithology. It includes explorers, early collectors, and professional ornithologists who have worked in the province. But most contributors were farmers, ranchers, teachers, physicians, accountants, homemakers, etc. who shared a common love of natural history and birds. On almost every page, I found the name of someone who encouraged or supported a bird-crazy teenager on my path to a career in ornithology. I know that many others of my cohort (including the senior editor) shared this experience, and that it continues today, guaranteeing that Saskatchewan ornithology will thrive in the 21st century.

The book ends with a "Literature Cited" section spanning 49 pages and including approximately 2500 entries (my estimate)! I suspect that there few (if any) publications relevant to the avifauna of Saskatchewan that have been overlooked. Future researchers now have a single place to access relevant citations covering information on observations and research from 1690 to 2016.

Birds of Saskatchewan is an important record of the history and current state of the avian fauna of the province. It brings together a wealth of information that will be useful to both bird enthusiasts and future scholars. Beyond that, it is a delight to move through the pages, sampling both the data and the biological details contained. Its price is well worth the rewards of exploring a remarkable book.

M. Ross LEIN
University of Calgary, Calgary, AB, Canada

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Feed the Birds: Attract and Identify 196 Common North American Birds

By Chris Earley. 2019. Firefly Books. 296 pages, 29.95 CAD / 24.95 USD, Paper.

Chris Earley's book, *Feed the Birds: Attract and Identify 196 Common North American Birds*, couldn't have come at a better time. In October 2019, a landmark paper was published documenting the catastrophic decline in North American avifauna. Rosenberg *et al*. (2019: 120) wrote that their analyses indicate "a net loss approaching 3 billion birds, or 29% of 1970 abundance". With an overall decline of avian species, even common species, we need to do everything we can to help our feathered friends.

Feed the Birds is an easy-to-use book geared toward aiding in bird observation and study. The book begins with a brief introduction, asking questions like "why feed birds?" and delving into possible answers, such as citizen science, involving kids in birding, and photography. After the introduction, the book is divided into two major sections: (1) attracting and feeding birds and (2) identifying birds. The first section has four chapters: "Feeding Wild Birds" (what and how to feed); "Creating a Bird Friendly Backyard" (natural foods, water, shelter, nesting boxes, predators, etc.); "Bird Feeder Building Plans"; and "Bird Behavior and Biology" (recognizing individual birds, nature's predators, predator detectors, adaptions). The second section (comprising half the book) is focussed on bird identification, from hummingbirds and woodpeckers to grosbeaks and orioles. The book ends with a blank "birds at my feeder list", works cited, further reading, photo credits, and an index.

The first section is a joy to read. The writing is not long-winded and gets to the point. The paragraphs are packed with information, and each page is loaded with colour photos to support the text. For example, feeding wild birds is much more than tossing out a simple hardware store seed mix. Certain birds require certain kinds of food; different types of seeds attract different species of birds and some bird food types aren't even seeds, like suet, fruits and jellies, nectar, and mealworms. What do you do with these foods? Toss them on the ground? Not always. There is a whole philosophy behind bird feeders and dispensers and, depending on what you want to attract to your yard, these feeders are critical. Creating a bird-friendly yard can also enhance the avian biodiversity in your area. Supplying a water source, nesting areas, shelters, and bird-attracting plants will no doubt increase the number of birds in your yard. There are many things one needs to consider such as native versus non-native plants, berry-bearing shrubs and trees, plants that support invertebrates, and flowers that attract hummingbirds and other nectar feeders. Other must-read sections include how cats impact birds and the balance between enjoying the squirrels in your yard and when they become too much of a pest at the expense of your bird friends. Birds crashing into windows is another issue, and the book addresses this as well.

As you watch the birds in your yard, you will begin to take note of various behaviours that may seem baffling at first, but with careful study, the mysteries of bird interactions, aggressive displays, and courtship begin to tease out and demystify. Chapter 4, "Bird Behavior and Biology", is a fascinating and welcome addition to your reading adventure. Various topics are covered, including feather maintenance, feeding behaviour, threat displays, nestling care, and bird intelligence. It's always a joy to watch jays and crows figure out bird feeders as well as harass pesky squirrels.

Of course, the biggest draw to attracting birds to your yard is bird identification. It's an incredible thrill to keep a tally of bird species (life lists) and to add a rare bird from time to time. One huge reward is knowing that the bird likely arrived in your yard simply because of the extra effort made to convert a once barren space into a bird paradise. The book discusses tips on how to identify birds, from size and shape, to beak morphology, bird movement, and field marks. The book includes a bird quick-find guide that assists in figuring out bird species, even if you only see the bird for a few moments. The guide will then direct you to a general bird group that will help with further identification. The general groups make up the last half of the book. Each group has species accounts, typically a page each, that provide additional information about the bird. Account topics include a general introduction to the bird, what natural foods they prefer, what feeds should be available in your yard, size comparisons, field identification marks, and a range map. All accounts are supported by several full colour photos of the bird species and sometimes additional side-by-side photo comparisons of closely related or resembling species. Along the bottom of each account is a small call-out box with a photo and natural history tidbit or anecdote about the bird. For example, in the American Robin account, the author discusses his observation of a robin "anting", that is,

allowing ants to crawl on its feathers, crushing them, and rubbing the ants through the feathers. Anting is thought to be a form of chemical application to help repel external parasites.

Overall, *Feed the Birds* is a must-read for those interested in attracting birds to their yard. With the general decline in bird species in North America and elsewhere, now is the time to create as many bird friendly spaces as possible. Chris Earley's book is a one-stop shop for all you need to know to move forward with this wildlife enhancing concept. It's easy to do and, with minimal effort, we can enjoy bird watching without even leaving the house. Be sure to participate in citizen science projects, like iNaturalist or eBird, and let's do our part to conserve and preserve avian biodiversity.

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HOWARD O. CLARK, JR.
Colibri Ecological Consulting, LLC,
Fresno, California, USA

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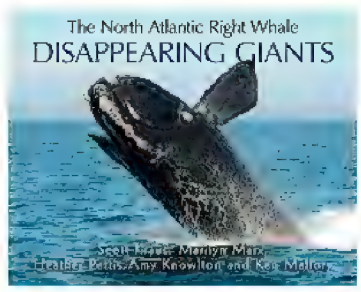
ZOOLOGY

The North Atlantic Right Whale: Disappearing Giants. Revised and Updated Edition

By Scott Kraus, Marilyn Marx, Heather Pettis, Amy Knowlton, and Kenneth Mallory. 2019. Fitzhenry & Whiteside. 140 pages, 24.95 USD, Paper.



North Atlantic Right Whales (NARW; *Eubalaena glacialis*) have been in the news quite a bit over the last three years in Canada, beginning in 2017 with the deaths of 12 NARW in the Gulf of St. Lawrence. This may not seem like a huge number, but with around 400 individuals left, mortality events like this are noteworthy. The Government of Canada acted surprisingly quickly, enacting vessel slowdown measures and fisheries closures to reduce the risk of ship strikes and entanglements, respectively. This management strategy apparently worked, with no NARW found dead in Canadian waters in 2018. But 2019 was a dire season again, with eight or nine NARW found dead in Canadian waters. The National Oceanic and Atmospheric Administration of the United States have even labelled these mortalities as Unusual Mortality Events. *Disappearing Giants* outlines the plight of NARW, paying particular attention to the recent Unusual Mortality Event that the population underwent. This book provides a useful, relatively concise overview of the conservation issues surrounding this species, and could be especially interesting for Canadian readers who want to learn more about this species following the recent deaths in the Gulf of St. Lawrence.

Disappearing Giants is a clearly written, non-technical overview of NARW, filled with wonderful photos of the whales. Close to 50% of the book is filled with photos, so beyond the interesting content, it would be a great book to leave out on a coffee table. This book is written by researchers from the New England Aquarium, some of whom, including main author Kraus, have been studying NARW since the 1970s. The book educates readers about NARW, with a brief chapter on evolution, followed by their history with humans, starting with centuries of whaling that devastated the population, to current research and threats to the species. While all of the 14 species of baleen or great whales (Mysticetes) were target species for whalers, the 'right whales' to hunt were the three species of right whales (*Eubalaena* spp., including NARW) and Bowhead Whales (*Balaena mysticetus*; Family Balaenidae) because they were easier to recover after they were killed: when they die, they tend to float on the surface, unlike rorqual whales (Family Balaenopteridae) that typically sink once they die. The commercial hunt for NARW ended in 1935 and, at that point, it was thought that only 100 whales were left. The population has recovered since then, but not as well as other right whale species, such as Southern Right Whales (*Eubalaena australis*). A main reason for this difference is that NARW live along the Atlantic coast of North America, where they are constantly exposed to ship traffic and active fishing grounds, leading to continued human-caused mortality.

Disappearing Giants doesn't just focus on the bleak history of NARW. It ends on a chapter called "Hope for the Future", where the authors describe reasons why we shouldn't give up on NARW, and should continue working towards helping this species recover. The authors outline recent management initiatives that have been quite effective in reducing mortalities of NARW and, perhaps most importantly, describe the collaborative nature of NARW conservation initiatives, where like-minded people have come together to address conservation issues surrounding NARW. These collaborations are a crucial aspect of the recovery of this species, and do indeed give me hope that the conservation issues surrounding NARW are solvable, which will hopefully lead to recovery.

WILLIAM D. HALLIDAY
Wildlife Conservation Society Canada,
Whitehorse, YT, and
Department of Biology, University of Victoria,
Victoria, BC

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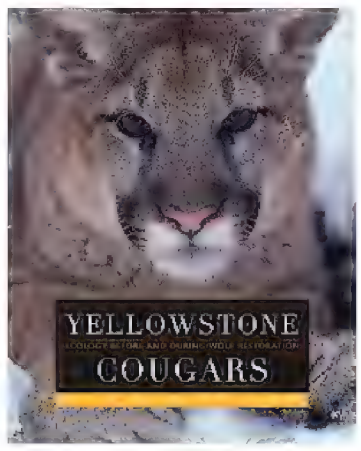
Yellowstone Cougars: Ecology Before and During Wolf Restoration

By Toni K. Ruth, Polly C. Buotte, and Maurice G. Hornocker. 2019. University Press of Colorado. 336 pages, 65.00 USD, Cloth, 53.00 USD, E-book.



Yellowstone Cougars is an academic-style book written primarily for biologists and wildlife managers. It contains a treasure trove of data on Cougar (*Puma concolor*) and is the first book written on an apex carnivore to examine their ecology before and after the recovery of another keystone predator—in this case, Gray Wolf (*Canis lupus*). Given its scientific focus, the reading is very dense and time consuming with an impressive amount of data within its 300+ pages. The 8.25 × 10.25 inch (20.8 × 26.1 cm) hardcover contains small font and double columns per page so the book really felt like over 500 pages! Each chapter took me a couple hours to read given the length along with the technical information on each page. However, everything you want to know about Cougars in the world's first national park is told here. This book and *Cougar: Ecology and Conservation* (2010, University of Chicago Press) are now the two reference books for this animal to which other works will be compared.

Ruth and her colleagues conducted a 14-year study—seven years before wolves returned to Yellowstone National Park (1987–1994) and seven years (1998–2005) covering the tail end of wolf reintroduction to the beginning of a recovered population. The book is broken into five main sections, the first consisting of three introductory chapters discussing their methods and the study area, followed by three middle sections on Cougar diet and their competition with wolves (five chapters), landscape use (four chapters), and Cougar population characteristics pre- and post-wolf recovery (four chapters), and the final section contains two synthesis chapters on carnivores and humans. Each of the three middle sections has an introductory chapter which frames where the next three to four chapters will take us. Each chapter ends with a convenient summary of the most pertinent information from that section, making it easier to digest the scientific information presented in that chapter—I often read those sections first before starting each chapter, then re-read it after I finished a given chapter.

The authors spent an amazing amount of time in the field, marking 87–94% of the adult Cougars annually with 80 total Cougars radio-collared and ear-tagged (including all age classes) during pre-wolf studies and 88–93% post-wolf adult Cougars collared annually with 83 total tagged post-wolf (pp. 28, 69). Cougars were treed by hounds and then darted by biologists to sedate them. They were then followed so their movements and predation patterns could be recorded, with 40–50 kills found annually (p. 34). The researchers collected about 12 000 VHF (very high frequency) radio locations and over 19 500 GPS (global positioning system) points on these animals over 14 years. Their study area consisted mainly of the Northern Range of Yellowstone because Cougars only seasonally lived in the remaining 75–80% of the park due to deep snow and ungulates leaving those areas in winter, except for Bison (*Bison bison*) which they did not prey on (p. 58).

We learned that Cougars were at the bottom of the large carnivore hierarchy, with wolves and Grizzly Bears (*Ursus arctos*) dominating them (pp. 93, 116), wolves most commonly, though rarely, killing them and bears most frequently usurping their kills (p. 244). Elk (*Cervus canadensis*) were the staple prey for Cougars and wolves throughout both study periods, with Mule Deer (*Odocoileus hemionus*) second for Cougars (p. 50). Calf Elk were the most important prey class throughout the study for Cougars (p. 52). This remained the case even when Elk decreased at the end of the study owing to recovery of carnivore populations, including bears, causing the system to change from bottom-up regulation of Elk before wolves to top-down post-wolf (p. 117). In general, wolves were superior at exploiting Elk adults and Cougars at exploiting Elk calves. Given their high niche overlap (82%, pp. 243–244), the sympatric carnivores were unwittingly engaged in exploitation competition for a common food source (pp. 119, 244).

Cougars survived by avoiding competitors, mainly wolves, by living in more forested and rougher terrain (p. 62), which contained a lower density of prey (p. 66). When prey Cougars killed was not taken over by competitors, Cougars often spent two to five days at a carcass before moving on to travel and eventually kill again, usually three to four days after leaving their previous food cache (pp. 71–73). The authors believed that Cougars benefited from using areas of lower densities of prey as this reduced potentially fatal encounters with wolves (pp. 179, 240, 242). Even so, wolves killed at least three adult Cougars and five kittens during the study (pp. 180, 208, 212).

Interestingly, Cougar home ranges and core areas were more stable after wolf restoration compared to before (pp. 134–136). While Cougars used less area (females 10–46% and males 43–65%) on the landscape

when wolves were back, they overlapped with more conspecifics sharing non-defended areas (i.e., females and philopatric daughters; pp. 137–138). In avoiding open and flat areas when wolves were back on the landscape, the authors repeatedly stressed the importance of forested and rough terrain for Cougars (e.g., pp. 159, 176, 181, 235). The heterogenous habitats of northern Yellowstone likely makes carnivore coexistence possible as each species used different areas (pp. 181, 242).

Some unexpected findings of the study were, despite wolves engaging in exploitation (eating similar prey) and interference (direct killing) competition with Cougars, the cats had similar litter sizes (averaging 2.9 cubs) throughout the study (p. 216) and kitten survival actually increased post-wolf (pp. 216, 202, 205) with less infanticide by adult male Cougars (p. 212). Because territories were more stable post-wolf, kittens actually stayed with their mothers for five months longer (12–14 versus 17–19 months) than before wolves came back (pp. 204, 220, 240), and living in small groups of adult-sized Cougars likely offered enhanced protection, intimidation, and vigilance from other predators (p. 230). In addition, the Cougar population increased post-wolf with about 30–40 total Cougars living in northern Yellowstone despite using a smaller percentage of overall habitat in the park (pp. 226, 230). Part of this can be explained by Cougars recolonizing the area in the 1980s (p. 21) and then becoming saturated on the landscape as wolves came back. Densities of Cougars of two adults and 3.9 total per 100 km^2 in the study area were actually on the high end compared to other Cougar populations (p. 225). With this fully occupied area, females—with no room to stay near their mothers—averaged the same dispersal distance as young males (70 km; p. 221) and females moved more home range diameters away than did males (pp. 224, 254). Similarly, while 35% of females before wolves were philopatric only 11% were so post-wolf (p. 220). These young dispersers contributed to Yellowstone being a source population to nearby areas (pp. 255–256). Source populations are helping Cougars recover and colonize long vacant areas like the midwestern and even eastern United States (Way 2017: 249).

Yellowstone Cougars is comparable to the incredibly detailed and well-researched books *Desert Puma* (2001, Island Press) and *Mountain Lions of the Black Hills* (2018, Johns Hopkins University Press; Way 2018) in that it does a superb job of describing an in-depth long-term study on Cougars in a specific region. *Yellowstone Cougars* includes: 10 pages of Appendices explaining their study variables; 10 pages of "Notes" which are detailed statistics described in the chapters but shown at the end of the book to avoid too much detail in each section; an impressive 30 pages of double-columned references; and a seven-page index. It takes six pages at the beginning of the book to list the titles of the illustrations, including 118 figures and 60 tables. Many of those figures are black and white pictures of wild Cougars from the study, impressive because Cougars are notoriously difficult to photograph. My only complaint was that there was no map displaying dispersal distances from the source population when the authors discussed emigration (pp. 219, 221). Also, I did notice a few errors on some of the figures, including wrong labels in the charts (e.g., Figure 11.1 on p. 155, Figure 11.14 on p. 173, Figure 15.4 on p. 207, and Figure 16.4 on p. 230).

The reading material is labourious to go through thoroughly but is vital to understanding Cougar ecology in Yellowstone. I found Part 5, *Carnivores and Humans: Competition and Coexistence*, to be particularly important because it provided a synthesis of the book and offered management and conservation recommendations for the big cats. I was a little disappointed with the last chapter (18) in that it described management and conservation of Cougars but did not actually offer any concrete management options for state agencies. For instance, their data (see Figure 18.1, p. 253) showed that many female Cougars killed by hunters left orphaned offspring that died via starvation (p. 250). The authors do suggest management regimes where non-parklands also include areas closed to hunting to mimic natural populations (p. 250). These areas can be managed adaptively through rest rotation, whereby periods of hunting alternate with periods of rest (p. 248). However, without any specific suggestions of where these could occur, my experience with carnivore management suggests that even with involving citizens in a bottom-up approach (p. 258) it is difficult to envision state wildlife agencies doing anything other than continuing with killing the maximum sustainable amount of a species—even an ecologically important predator.

For enthusiasts of Yellowstone or carnivores, this is an important book. Unfortunately, and like many academic-style texts, *Yellowstone Cougars* is expensive. However, the book is truly a benchmark in detailing the life history of an elusive and difficult to study species.

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JONATHAN (JON) WAY

Eastern Coyote/Coywolf Research,
Osterville, MA, USA

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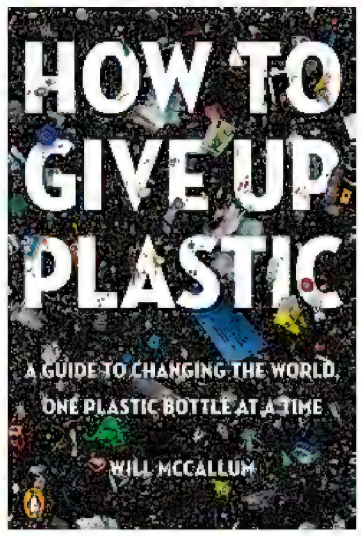
OTHER

How to Give Up Plastic: A Guide to Changing the World, One Plastic Bottle at a Time

By Will McCallum. 2018. Penguin Random House. 224 pages, 15.00 USD, Paper.



Plastic. No matter where we look, it is everywhere, whether we see it or not. The impact that plastic has been having on wildlife and ecosystems has extended past the environmental field and has exploded into mainstream media. It can almost feel like we are bombarded by the various ways to become more eco-friendly and adopt a zero-waste lifestyle, leaving many people feeling like their contributions will be minimal at best. As someone who is always trying to reduce their footprint and encouraging others to do the same, this book was one I was particularly excited to check out.

How to Give Up Plastic begins with a wake-up call. The first two chapters focus entirely on the plastic problem and include many astonishing statistics and research that I was unfamiliar with. It was very interesting to learn the history of how plastics became so prevalent in our lives, how they have evolved, and how our recycling systems are not what we, as regular consumers, believe them to be. These chapters paint a somewhat glum picture of where our reliance on plastic has brought us, countered in the next chapter, "Stories of Hope and Success", showing how one person or one group created a huge difference in their community and beyond. Throughout the book you can find mini interviews relating the experiences of people leading the charge in the fight against plastics. I thoroughly enjoyed reading their views, tips, and reasons for doing the work that they do.

The next five chapters take us through different areas in our homes and lives. Each chapter breaks its area down into the most common items one might use (for example, the bathroom chapter includes sections on lip balm, shampoo, make-up, and hair removal). Some of the categories mention businesses that are targetting certain waste forms by creating alternatives. This information is very helpful in giving you a place to begin searching for items that suit your lifestyle; however, it could go quickly out of date as businesses come and go. While most of this advice is available through internet searches, having it all in one location to read through puts the bigger picture together and allows you to see where you want your plastic-free life to begin. As someone who has begun changing my lifestyle to lessen my waste and use of single-use plastics, I was happy to find many items that weren't on my radar and a few new blog suggestions! Many of the chapters end with a work page where you can list your plastic-free plan based on the topics covered.

Chapters 10 and 11 take you from targetting your individual plastic use to your workplace and community. They are full of ideas, from getting people motivated to using your vocabulary to engage others to join the cause. The chapter on community gives a step-by-step guide to running your own clean-up, writing an effective letter to your members of government, and hosting a protest. These are activities that I think many people would like to be involved in and this allows them to take the next step in the actual planning process.

This is a great book for those who are relatively new to being plastic-free. It has tips and tricks for your everyday life and acts as an easy access, easy-to-read guide to start making your plastic-free plan. What felt like almost a blog-type format kept the content engaging and easy to read. I appreciated that the author consistently highlighted the need for systemic change, beginning with the industry, and an understanding that different realities exist for different people and can inhibit their ability to fully give up plastics. I typically expect books like this to be relatively preachy, but I also appreciated the fact that the author did a good job of being non-judgemental while still giving solid advice and statistics on the repercussions of plastic use. I would recommend this book to anyone interesting in beginning to reduce the amount of plastic in their life or anyone currently on the plastic-free journey as it may provide some topics they haven't thought of yet.

TIANNA BURKE

Conservation Biologist, Georgian Bay Biosphere Reserve, Parry Sound, ON

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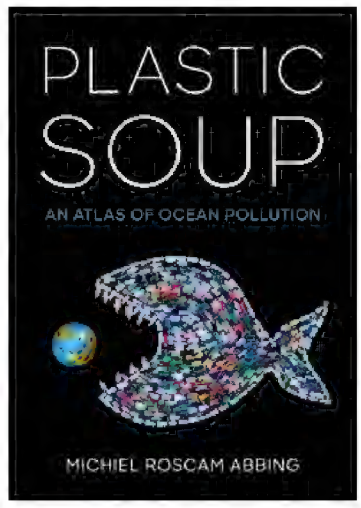
Plastic Soup: An Atlas of Ocean Pollution

By Michiel Roscam Abbing. 2019. Island Press. 136 pages, 27.00 CAD, Cloth or E-book.



Plastic is in almost every item we use and own. Its convenience as a relatively cheap and durable material has become rather inconvenient from an environmental standpoint. For a few years now I have personally tried to make my household less reliant on plastic and am continuously surprised at just how difficult it is. Whether it is purchasing food, soap, pet products, or craft supplies, it has been incredibly difficult to manoeuver in a world where things are not individually wrapped or contain plastic.

Plastic Soup: An Atlas of Ocean Pollution is a short book with a lot of impact, both by the written content and the visual content. Author Michiel Roscam Abbing is a political scientist actively working on the plastic soup problem since 2011 alongside the Plastic Soup Foundation. Trying to put an end to increasing amount of plastic pollution, the Plastic Soup Foundation works to tackle plastic issues at the source, something that is focussed on in this book.

Plastic Soup is separated into two distinct parts; the first, "On the Map", focusses on the plastic crisis: its creation, the effects plastic has on ecosystems and wildlife, and some of the major items contributing to the plastic problem. The second half of the book, "Off the Map", focusses on solving the plastic crisis, highlighting research and initiatives around the world, the introduction of laws, and even how art is bringing this issue into the forefront.

More than just an atlas of pollution, this book is also an atlas of hope. I found it so interesting to learn how many different stakeholders across the world are reducing the use of plastic. Being someone who loves food, the idea of lasered food to reduce packaging and stickers was especially of interest. This book also challenged the optics of plastic itself and some of the plastic solutions that are becoming popular. I found it interesting to read that, technically, plastic reduces food waste because it helps to extend the shelf life of many items. Similarly, it takes fewer emissions and less water to produce than paper does, another common packaging item. However, while this may seem like plastic is an obvious solution, the total lifecycle of the product says otherwise, emphasizing the need to think critically and in terms of lifecycles.

Critical thinking came up again in Chapter 7, "Between Belief and Hope", which tackles subjects such as recycling, bioplastics, and creating products out of ocean plastic. While these ideas may seem brilliant, they may be better than the actual results. Many books tend to focus on what you can do at an individual level and, while this book points out the roles our purchasing and lifestyle choices play, I was impressed by the author's emphasis on change at a level greater than a household. It helped me realize what more I can be doing at home and provided ideas I can push through to my local municipality and government.

I really enjoyed how in this first section the topics moved from obvious plastics, such as balloons, to plastics that we cannot see, such as microplastics. The author did a great job informing the reader of the problems and delivering the scientific evidence in a way that reaches all audiences. It was easy to understand, and the written content was enhanced by stunning photography and infographics. The format of the book makes it easy to read, providing a valuable tool for people seeking to learn more about the plastics issue. Throughout, heart-wrenching images bring home very effectively the message of the damage plastic has done to our planet and wildlife. Even if you don't read the book, the images alone will make you want to change your habits! I would recommend this book to anyone who is interested in learning more about plastics or for those, like me, who are trying to teach others and could use a resource jam-packed with information.

TIANNA BURKE

Conservation Biologist, Georgian Bay Biosphere Reserve, Parry Sound, ON

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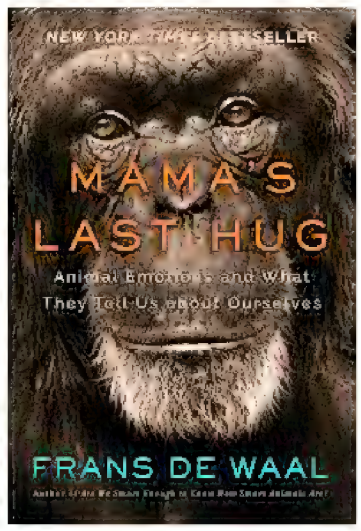
Mama's Last Hug: Animal and Human Emotions

By Frans de Waal. 2019. W.W. Norton. 336 pages, 36.95 USD, Paper.



Humans have held themselves superior to all other life forms for millennia. Dating back to Aristotle, this attitude in Western cultures was crystalized in the biblical notion that 'man will have dominion over the earth and all the creatures therein'. The consequences of this belief, and the subsequent actions over succeeding millennia, have been disastrous for the animals, as well as the earth itself. While ecologists, environmentalists, and most students of the life sciences are increasingly recognizing, defining, and warning us of these consequences, the notion of human supremacy is one that still remains strong. Why this should be so is a key question that primatologist Frans de Waal addresses in this, his 12th book, a "companion" to his *Are We Smart Enough to Know How Smart Animals Are?*, published by Norton in 2016. As de Waal explains in his Acknowledgments, "[e]ven though these two books treat emotions and cognition separately, in real life they are fully integrated" (p. 279). The arguments for animal intelligence and emotional lives presented by de Waal are compelling, supported by the increasing research in these areas and the rich anecdotal evidence gathered during his own long experience with primates and from other primatologists.

Mama's Last Hug begins with just such a story. We meet Mama as a 50-year-old Chimpanzee on her death bed. A researcher who had spent much time with her but who had not seen her in several years appeared for a final visit. On seeing him, Mama was transformed, from a listless animal on its way out to an excited, expressive creature that greeted her old friend effusively. How this could be seen in any other way as an emotional response is the mystery that de Waal seeks to unravel.

After a brief Prologue, the book continues for seven chapters. The first, "Mama's Last Hug", relates the story noted above; the next three discuss various emotions. Many of us conflate emotions with feelings, but de Waal distinguishes between them, defining feelings as interior states that we can describe using language and emotions as the deeply rooted, initially subconscious states that emerge into consciousness during various situations. The distinction is helpful, allowing him to address the idea that because animals don't have words to express emotion, they do not feel emotion; they simply react behaviourally to various stimuli in instinctual ways. This idea is not to be underestimated in its force—centuries of animal research have been premised on it. Chapters 2 and 3 present evidence of positive emotions in animals—laughter, empathy, sympathy—while Chapter 4, "Emotions That Make Us Human", deals with negative emotions, including disgust, guilt, and shame. These chapters contain many instances, observed in the wild or concluded from ingenious experiments, demonstrating the reality of animal emotional lives. Two themes running through these chapters, and indeed the book, are the continuity between the behavioural responses of apes and humans, and the continuing, though diminishing, resistance of scientists to accept or, more accurately, to write as though they accept, that apes have emotions just as humans do.

These chapters are the foundation for the more difficult, controversial discussions in the next three, Chapter 5, "Will to Power – Politics, Murder, Warfare", Chapter 6, "Emotional Intelligence – On Fairness and Free Will", and Chapter 7, "Sentience – What Animals Feel". If you cannot accept that animals have emotions, then it will be next to impossible to accept, as argued in Chapters 5 and 6, that animals have complex political relations, can engage in murder and warfare, or choose to act with fairness, and have the capacity to think through the consequences presented at times decisions are required. But the evidence is strong, the stories compelling. If one accepts evolutionary continuity between apes and humans, de Waal's conclusions are inescapable.

Chapter 7 is the capstone of the book. It begins by exploding the long-held belief that human superiority is based on the size of our brains and number of neurons therein. Recent research has shown that elephants have more of both than we do! And the related myth that consciousness is a property of humans alone gets similar treatment. Not only that, but instinct as sole explainer of animal actions is itself relegated to the dustbin of historical ideas. In the process of making these remarkable conclusions, de Waal discusses "three reasons (apart from pressing ecological ones) that humans should respect all forms of life: the inherent *dignity* of all living things, the *interest* every form of life has in its own existence and survival, and *sentience* and the capacity for suffering" (p. 245; italics in the original). He admits that assigning dignity to all forms of life is based on our subjective evaluations, the danger we must guard against is falling back into the ancient concept of what the Elizabethans called the great chain of being.

It is more readily seen that living things have an interest in remaining alive. While this is obvious from the reactions of animals, from mammals to arthropods, it remains true of plants, which, science is discovering, have incredibly complex defensive systems.

The big reason for respecting all forms of life, however, is sentience, the idea, impossible to confirm with scientific certainty, that animals have conscious experience of their emotions. Surely this must be an essentially human capacity. Well, not so surely, it turns out. All creatures, from cells to fungi, plants, and animals, have some capacity for sentience, or the ability to adjust their experienced conditions. But "[s]entience in the narrow sense implies subjective feeling states, such as pain and pleasure" (p. 248). It is de Waal's view that all living creatures, with and without brains and central nervous systems, should be considered as "sentient in the sense of having subjective feeling states" (p. 249). And this form of sentience resulted, de Waal believes, in the development of consciousness "relatively early in evolution" (p. 255).

The acceptance of these ideas is still ongoing, although science has come a long way from the early days of research into "affective neuroscience", a discipline founded by Jaak Panksepp, who "was ahead of his time..." (p. 256). In Panksepp's day, relates de Waal, funding for such research was difficult to come by, so strong was the opposition to animal emotions and intelligence, particularly in the field of psychology, dominated by Skinnerian behaviourism. My first degree was in psychology during the heyday of this movement, which I rejected instinctively. I took a personal delight in reading de Waal's description of the movement's demise. Unfortunately, its lingering legacy is the "gap between humans and all other species, which only widened with time" (p. 260). The results of that gap are still being promulgated in books celebrating human exceptionalism, but meanwhile, "[b]ehaviourism is dying a slow death" (p. 262). And about time. As noted in my review (Cottam 2018) of *Through a Glass Brightly*, people who reject the notion that humans are animals need to elevate their concepts of what animals are. Personally, I find it comforting to think that rather than dwelling on some fictional peak, we humans are connected with all living matter, part of the great natural cycle of life and death, the only 'eternity'—should we manage not to destroy the earth—that we can know.

Much of the evidence in this book is derived from field experience, whether in the jungles and other habitats where the animals live, or in the humane environments in which many research animals now reside, relatively free to interact in their normal social ways. It's highly readable 'popular' science at its best, but the topics are huge and critically important, the concepts revolutionary if we accept them. Thus it provides some hope that we humans will realize that continuing to consider ourselves superior to all other forms of life is just what it takes to destroy our own.

Editor's note: I used an advance reading copy to review this book. The final publication will differ somewhat—it will be indexed, for example, and has a different cover—so page numbers for quotations in this review may not exactly match those in the published version.

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BARRY COTTAM

Corraville, PE, and Ottawa, ON

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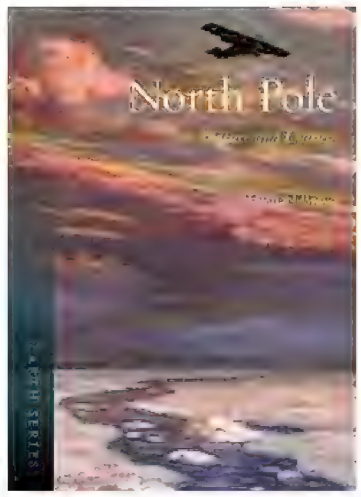
North Pole: Nature and Culture

Michael Bravo. 2019. Reaktion Books. 254 pages and 111 illustrations, 62 in colour. 24.95 USD, Cloth or E-book.



Michael Bravo, Head of Circumpolar History and Public Policy Research at the Scott Polar Research Institute, Cambridge, United Kingdom, has written a rather unusual book. As the title suggests, it deals with the North Pole, but it is extraordinarily eclectic, ranging from classical writings on the polar regions, through the speculations of renaissance geographers, to accounts of polar exploration in the 18th through 20th centuries, and includes diversions into different sorts of poles (astronomical, geographical, magnetic) and polar exploration in cartoons and satirical writing. We meet Madame Blavatsky, Scipio Africanus, Herakles, and Baron Munchausen, among many others. Some are characters we might expect to see at the North Pole (Peary, Amundsen, Nansen), while others come as a total surprise (Mary Shelley and Frankenstein, Ptolemy, Bal Gangadhar Tilak).

This is not a book for those who primarily want factual information about the North Pole, although some of that is included. It is more likely to appeal to those who enjoy a ramble through miscellaneous polar 'factoids'. Among the great names of polar travel, Peary gets quite a bit of space, although the controversy about where he actually got to is referenced but not described in detail, and Cook only gets passing mention. Steffanson, although never attempting to approach the pole, gets fairly extensive treatment, but I felt that Nansen got rather short shrift.

There is much in the book to be cherished regarding the impact of the pole on literature and art, and there are some lovely and, I suspect, little-known, images. However, I was constantly asking myself whether the book is really serious or a very well-disguised send-up of arcane scholarship. For example, after mentioning the section in Winnie-the-Pooh where Pooh finds a pole (he "just found it") and Christopher Robin announces that it must be the North Pole, Bravo makes the following suggestion (p. 158):

> Milne, diverging from ethnonationalists who elevated the status of the North Pole to that of an ur-site of Aryan origins, recognised it for what it was, the essential point of origin in a mathematical projection but philosophically no more special than anywhere else …

The book is very attractively produced and illustrated on wonderful glossy paper. It is very entertaining to thumb through and browse and only the most diligent student of things polar is likely to be familiar with all the material covered. However, the Pooh excerpt given above is just a rather extreme example of the book's generally over-erudite and, to my mind, over-elaborate, approach to the topic. Recommended for generalists and romantics. Not recommended for those only wanting information on polar exploration.

TONY GASTON
Ottawa, ON

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NEW TITLES

Prepared by Barry Cottam

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Animal Welfare in a Changing World. Edited by Andrew Butterworth. 2018. CABI. 320 pages, 140.00 USD, Cloth, 75.00 USD, Paper.

Being a Scientist: Tools for Science Students. By Michael H. Schmidt. 2019. University of Toronto Press. 320 pages, 63.75 CAD, Cloth, 36.95 CAD, Paper, 26.95 CAD, E-book.

That Wild Country: An Epic Journey through the Past, Present, and Future of America's Public Lands. By Mark Kenyon. 2019. Little A [Amazon Publishing imprint]. 300 pages, 31.12 CAD, Cloth, 14.42 CAD, Paper.

Extinction Studies: Stories of Time, Death, and Generations. Edited by Deborah Bird Rose, Thom van Dooren, and Matthew Chrulew. Foreword by Cary Wolfe. 2017. Columbia University Press. 256 pages, 90.00 USD, Cloth, 30.00 USD, Paper or E-book.

The Fruitful City: The Enduring Power of the Urban Food Forest. By Helena Moncrieff. 2018. ECW Press. 224 pages, 22.95 CAD, Paper, 16.99 CAD, E-book.

Geology of New Brunswick and Prince Edward Island Field Guide. 2019. Boulder Books. 300 pages, 34.95 CAD, Paper.

Modern Plant Hunters: Adventures in Pursuit of Extraordinary Plants. By Sandy Primrose. 2020. Pimpernel Press. 272 pages, 30.00 GBP, Cloth.

North America's Galapagos: The Historic Channel Islands Biological Survey. By Corinne Heyning Laverty. 2019. University of Utah Press. 384 pages, 29.95 USD, Paper, 24.00 USD, E-book.

Overrun: Dispatches from the Asian Carp Crisis. By Andrew Reeves. 2019. ECW Press. 384 pages, 22.95 CAD, Paper, 16.99 CAD, E-book.

Phylogenetic Diversity: Applications and Challenges in Biodiversity Science. Edited by Rosa A.

Scherson and Daniel P. Faith. 2018. Springer International Publishing. 224 pages, 159.99 USD, Cloth or Paper, 119.00 USD, E-book.

Sampling Theory for the Ecological and Natural Resource Sciences. By David G. Hankin, Michael S. Mohr, and Kenneth B. Newman. 2019. Oxford University Press. 368 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Smitten by Giraffe: My Life as a Citizen Scientist. Footprints Series, No. 22. By Anne Innis Dagg. 2016. McGill-Queen's University Press. 256 pages, 34.95 CAD, Cloth. Also available as an E-book.

Swamp: Nature and Culture. By Anthony Wilson. 2017. Reaktion Books. 248 pages, 14.95 GBP, Paper.

Synergistic Selection: How Cooperation Has Shaped Evolution and the Rise of Humankind. By Peter Corning. 2018. World Scientific. 304 pages, 78.00 USD, Cloth, 29.95 USD, Paper, 19.95 USD, E-book.

The Theory of Evolution: Principles, Concepts, and Assumptions. Edited by Samuel M. Scheiner and David P. Mindell. 2020. UCP. 464 pages, 120.00 USD, Cloth, 45.00 USD, Paper. Also available as an E-book.

Why Study Biology by the Sea? Edited by Karl S. Matlin, Jane Maienschein, and Rachel A. Ankeny. 2019. University of Chicago Press. 344 pages, 135.00 USD, Cloth, 45.00 USD, Paper or E-book.

News and Comment

Upcoming Meetings and Workshops

Alberta Chapter of The Wildlife Society Conference

The Alberta Chapter of The Wildlife Society Conference to be held 13–15 March 2020 at The Norsemen Inn, Camrose, Alberta. The theme of the conference is: 'Species on the Move'. Registration is currently open. More information is available at https://www.actws.ca/conference/.

Entomological Society of America, Joint North Central & Southwestern Branch Meeting

The 2020 Joint North Central & Southwestern Branch Meeting of the Entomological Society of America to be held 15–18 March 2020 at The Skirvin Hilton Oklahoma City, Oklahoma City, Oklahoma. Registration is currently open. More information is available at https://www.entsoc.org/2020-joint-northcentral-southwestern-branch-meeting.

Eastern Bird Banding Association Meeting

The 97th meeting of the Eastern Bird Banding Association to be held 27–29 March 2020 at the Hilton Garden Inn Mystic/Groton, Groton, Connecticut. The theme of the conference is: 'Using Bird Science to Inform Conservation'. Registration is currently open. More information is available at https://ebba2020.org/.

Entomological Society of America, 2020 Joint Eastern & Southeastern Branch Meeting

The 2020 Joint Eastern & Southeastern Branch Meeting of the Entomological Society of America to be held 29 March–1 April 2020 at the Sheraton Atlanta Hotel, Atlanta, Georgia. Registration is currently open. More information is available at https://www.entsoc.org/2020-joint-eastern-southeastern-branch-meeting.

American Fisheries Society, Western Division and Washington-British Columbia Chapters Annual Meeting

The annual meeting of the Western Division and Washington-British Columbia Chapters of the American Fisheries Society to be held 13–17 April 2020 at the Pinnacle Harbourfront Hotel, Vancouver, British Columbia. The theme of the conference is: 'Crossing Boundaries and Navigating Intersections'. Registration is currently open. More information is available at https://wa-bc.fisheries.org/2020-meeting/.

Northeast Natural History Conference

The 20th Northeast Natural History Conference to be held 17–19 April 2020 at the Hilton Stamford Hotel, Stamford, Connecticut. Registration is currently open. More information is available at https://www.eaglehill.us/NENHC_2020/NENHC2020.shtml.

Northeast Fish & Wildlife Conference

The 76th annual Northeast Fish & Wildlife Conference, hosted by the New Jersey Division of Fish and Wildlife, to be held 19–21 April 2020 at the Ocean Place Resort, Long Branch, New Jersey. The theme of the conference is: 'The Power of Partnerships'. Registration is currently open. More information is available at http://www.neafwa.org/conference.html.

Biodiversity Without Boundaries 2020 (NatureServe)

Biodiversity Without Boundaries 2020 to be held 19–22 April 2020 at the Richmond Marriott, Richmond, Virginia. Registration is currently open. More information is available at https://www.natureserve.org/news-events/events/biodiversity-without-boundaries-2020.

Entomological Society of America, Pacific Branch Meeting

The 104th annual meeting of the Pacific Branch of the Entomological Society of America to be held 19–22 April 2020 at The Centennial Hotel, Spokane, Washington. Registration is currently open. More information is available at https://www.entsoc.org/pacific/2020-branch-meeting.

Wild *Canis* spp. of North America: a pictorial representation

There has been considerable discussion of hybridization in the genus *Canis* in North America with the general consensus that the western Coyote (*Canis latrans*), Eastern Timber Wolf (*Canis lycaon*), and Gray Wolf (*Canis lupus*) hybridized to produce the Eastern Coyote/Coywolf (*Canis latrans* var. or *Canis latrans* × *lycaon*) and Great Lakes Wolf (*Canis lupus* × *lycaon*) in eastern North America (Rutledge *et al.* 2012, 2015; Way 2013; Way and Lynn 2016; Heppenheimer *et al.* 2018). Way (2013) described the five types of wild canids (*Canis* spp.; foxes excluded) in North America and noted that these canid groups were useful even with the few studies that claim that the Eastern Timber Wolf is not a distinct species but rather a hybrid between western Coyotes and Gray Wolves (von Holdt *et al.* 2011, 2016), despite the lack of field evidence that these two species mate and produce viable offspring (e.g., see Mech *et al.* 2014).

A comprehensive review of the taxonomy of wolves in North America supports the Eastern Timber Wolf as a distinct taxon (Chambers *et al.* 2012) as has most of the research on canids in eastern North America (see references in Rutledge *et al.* 2015, but see vonHoldt 2011 countering this). With this "*Canis* soup" of different, but closely related, species (there is gene flow from *C. lycaon* to *C. lupus* and from *C. lycaon* to *C. latrans* [Way 2013; Heppenheimer *et al.* 2018]), distinct species status for any canid complicates conservation efforts (including *C. lupus* in eastern North America). Furthermore, the degree of hybridization and terminology associated with these hybrids can be confusing for the layperson, for example, Way and Lynn's (2016) use of the term Coywolf versus Wheeldon and Patterson's (2017) use of the term Eastern Coyote.

Accordingly, we created a pictorial representation of *Canis* spp. in North America showing the six main types of canids: western Coyotes, Eastern Coyotes/Coywolves, Red Wolves, Eastern Timber Wolves, Great Lakes Wolves, and Gray Wolves (Figure 1). Because of the frequent separation of Red Wolf (*Canis rufus*), Eastern Timber Wolf, and Gray Wolf in analyses (e.g., von Holdt *et al.* 2011; Chambers *et al.* 2012) we show these canids separately even though others believe Red Wolf and Eastern Timber Wolf are the same species at opposite ends of their range (Wilson *et al.* 2000). This drawing represents average body sizes of one canid compared to another; however, it is important to realize the limitations of these average depictions. Even within a given type, males and females differ in size and there is considerable variation—where the size of one might be similar or even larger than the one adjacent. They may be difficult to tell apart in the field, not only from a distance, but even when captured, especially where their ranges overlap (e.g., in and around Algonquin Provincial Park, Ontario). This is further exemplified by Newsome *et al.* (2015) noting that even larger western Gray Wolves and smaller western Coyotes (which share no size overlap; Figure 1) are often difficult to tell apart from a distance and someone 'shooting a coyote can sometimes result in a dead wolf'. Natural expansion or recolonization of a range is a confounding factor (e.g., Eastern Timber Wolves or Great Lakes Wolves dispersing into southern Canada and the northeastern USA are just claimed to be

FIGURE 1. Wild *Canis* of North America. These drawings are intended to represent average body sizes of one canid compared to another. But within a given type, males and females differ in size and there is considerable variation such that the size of one might be similar or even larger than the one adjacent making them difficult to tell apart in the field, especially where ranges overlap. Also, while Red and Eastern Timber Wolf are considered separate here, many studies have indicated that they are possibly the same species (*Canis lycaon*) living on opposite ends of their eastern North American range. Drawings: J.L. Hirten.

heavy Eastern Coyotes). Often genetic testing is the only way to differentiate among *Canis* spp. in eastern North America (Rutledge *et al.* 2012).

Recent research acknowledges the importance of hybridization among closely related species and in the case of eastern wolves there is a need for managed introgression that focusses on preserving any eastern wolf genetic material in any genome regardless of their potential mosaic ancestry composition (Heppenheimer *et al.* 2018). If such an effort prioritizes and maintains individuals that carry admixed genomes, as Heppenheimer *et al.* (2018) suggest, then more common animals like the Eastern Coyote would be an important source of greater genetic variation and potential adaptive capacity. It is our hope that this diagram (Figure 1) is a useful guide to show the variation and types of *Canis* spp. in North America with a specific focus in eastern North America.

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JONATHAN G. WAY
Eastern Coyote Research, Osterville, MA, USA

JUSTINE LEE HIRTEN
Fairfield, CT, USA

In Memoriam: Francis Cook (3 March 1935–3 January 2020)

Francis Cook was the longest serving editor of *The Canadian Field-Naturalist*. He was editor of the journal for 34 years, from 1962 to 1966 and from 1981 to 2010. In total, Francis edited 35 volumes of *The Canadian Field-Naturalist*. He helped hundreds of researchers publish their work in the journal.

In addition to his work on *The Canadian Field-Naturalist,* Francis Cook was the Curator of Herpetology at what is now the Canadian Museum of Nature from 1960 to 1993, aside from a two-year educational leave to work on a Ph.D. at the University of Manitoba. Francis had a passion for herpetofauna that lasted a lifetime. He spent decades gathering data on the natural history of local amphibians near his home.

In 2018, Francis was awarded the Order of Canada for his research on amphibians and reptiles and for being the long-time editor of *The Canadian Field-Naturalist*. He was also honoured by the Ottawa Field-Naturalists' Club. He was selected as Member of Year in 1990 and 2010 for his efforts editing *The Canadian Field-Naturalist*, and he was made an Honorary Member of the Club in 1998 "For service to the Club and herpetological work". Francis's exceptional contributions to our understanding of the natural history of amphibians and reptiles (detailed in Halliday and Seburn 2018; Seburn and Halliday 2018) were honoured in special issues (volume 132, issues 1 and 2) of *The Canadian Field-Naturalist*, with the content of those issues dedicated to studies on Canadian amphibians and reptiles.

Francis Cook died in Kemptville on 3 January 2020. Memorial donations may be made to *The Canadian Field-Naturalist* if desired; you may direct an e-transfer to treasurer@ofnc.ca with a note "Re: The Canadian Field Naturalist in Memory of Francis Cook".

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Halliday, W.D., and D.C. Seburn. 2018. Introduction to the Special Issue on herpetology in Canada. Canadian Field-Naturalist 132: 1–3. https://doi.org/10.22621/cfn.v132i1.2113

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OFNC PUBLICATIONS COMMITTEE

The Canadian Field-Naturalist

Editors' Report for Volume 132 (2018)

Mailing dates for the four issues in volume 132 were: 24 October 2018, 31 January 2019, 2 May 2019, and 31 July 2019. Summaries of the distribution of paid subscribers to *The Canadian Field-Naturalist* for 2018 are provided in Table 1, along with comparison numbers for volume 131. This list does not include free copies distributed to Honorary Ottawa Field Naturalists' Club (OFNC) members or online access, which is included in OFNC membership dues. Institutional subscribers potentially represent many thousands of users. The number of articles published in volume 132 increased by 10 over the number published in volume 131 while the number of notes decreased by 10, with the same number of manuscripts published both years (Table 2). Not surprisingly, 25/45 (56%) of the manuscripts in 132 were on amphibians and reptiles, given the first two issues of 132 were Special Issues: studies on Canadian amphibians and reptiles in honour of Dr. Francis Cook. The three manuscripts in the "other" category were on alvars, Arctic slumps, and fungi (Table 2). The number of book reviews and new titles published in volume 132 were slightly up and down, respectively, over the numbers in volume 131 (Table 3). The total number of pages published increased by 36 for volume 132 over volume 131 (Table 4) with articles contributing 69% to the page count and 76% of manuscripts published (Table 2). There were no thematic collections (editor-selected compilations of previously published contributions in both *The Canadian Field-Naturalist* and the regional OFNC publication, *Trail & Landscape*, on a central theme with internet links to each article) nor articles on Greatest Canadian Field Naturalists, the latter of which were included in News and Comment in 131.

Table 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, Volume 132 (Volume 131), by major field of study.

Subject	Articles	Notes	Total
Mammals	3 (3)	0 (8)	3 (11)
Birds	3 (10)	2 (6)	5 (16)
Amphibians and Reptiles	19 (3)	6 (2)	25 (5)
Fishes	0 (1)	1 (2)	1 (3)
Plants	4 (3)	1 (2)	5 (5)
Insects	1 (1)	0 (0)	1 (1)
Non-insect invertebrates	1 (2)	1 (1)	2 (3)
Other	3 (1)	0 (0)	3 (1)
Total	34 (24)	11 (21)	45 (45)

Table 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 132 (Volume 131), by topic.

	Reviews	New Titles
Zoology	26 (15)	148 (155)
Botany	7 (7)	24 (43)
Miscellaneous	9 (18)	122 (111)
Total	42 (40)	294 (309)

Sixty-five manuscripts were submitted to *The Canadian Field-Naturalist* in 2018, eight more than in 2017; there were also two initial enquiries about suitability of topics for submission, one of which submitted formally in 2019. All except one manuscript was submitted using the Online Journal System, some (n = 9) after an initial email submission. Thirteen of the 65 were for the Special Issues on Canadian amphibians and reptiles. Only 11 of the 65 submitted manuscripts were not accepted for publication upon initial submission or review or were insufficiently revised to warrant publication. The remainder, 83.1%, were accepted or are undergoing revision and review. In 2017,

Table 1. The 2018 (2017) circulation of *The Canadian Field-Naturalist*. Compiled by Eleanor Zurbrigg from the subscription list for 132(4). This list does not include copies distributed to Honorary Members or online access which is included in OFNC membership fees.

Subscriber Type	Canada		USA		Other		Total	
OFNC Members	43	(51)	1	(4)	0	(0)	44	(55)
Subscriptions:								
Individual	26	(26)	7	(7)	0	(0)	33	(33)
Institutional	66	(73)	90	(106)	12	(12)	168	(191)
Total	135	(150)	98	(117)	12	(12)	245	(279)

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TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, volume 132 (131), by issue.

	Issue				Total
	1	2	3	4	
Editorials/Editors' Report*	3 (0)	4 (0)	3 (2)	0 (1)	10 (3)
Articles	51(67)	86 (47)	74 (47)	94 (42)	305 (203)
Notes	12 (7)	2 (17)	11 (30)	12 (27)	37 (81)
Thematic Collections	0 (5)	0 (8)	0 (0)	0 (0)	0 (13)
Tributes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Book Reviews†	18 (14)	18 (15)	18 (15)	8 (13)	62 (57)
News and Comment	2 (2)	2 (1)	2 (6)	2 (12)	8 (21)
Reports‡	12 (19)	0 (0)	0 (0)	0 (0)	12 (19)
Erratum	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Index	– (–)	– (–)	– (–)	8 (9)	8 (9)
Total	98 (114)	112 (88)	108 (100)	124 (104)	442 (406)

*Includes introductions to Special Issue Parts I and II.
†Includes reviews and new titles.
‡Includes Annual Business Meeting Minutes, Annual Committee Reports, and Awards, including the James Fletcher Award for best paper published in the volume; Financial Statements are only available online beginning with 132.

89.5% of the 57 submissions were accepted for publication and either published or underwent further revision and review.

Guest Editors William Halliday and Dave Seburn received the manuscripts submitted for the Special Issues, assigned reviewers, handled the review process, and passed the accepted manuscripts to Dwayne Lepitzki, *Editor-in-Chief*, and Amanda Martin, the *Assistant Editor*, for the rest of the publication process. Amanda edited content, proofread galleys, and sent and received author order and transfer of copyright forms; she also prepared the News and Comment. Sandra Garland and John Wilmshurst proof-read and copy edited manuscripts. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs. Barry Cottam, *Book Review Editor*, requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings. Ken Young sent page charge invoices to authors and tracked the budget while Eleanor Zurbrigg managing subscriptions and mailed printed copies. William Halliday, *Online Journal Manager* and *Webmaster*, provided digital content to subscribers, posted tables of contents, abstracts, and pdfs on *The Canadian Field-Naturalist* website, and prepared the Index. Our *Associate Editors* managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. Dave Seburn, our *Map Editor*, reviewed and provided suggestions for all the maps. The Publication Committee, chaired by Jeff Saarela and consisting of Annie Bélair, Dan Brunton, Carolyn Callaghan, Paul Catling, Barry Cottam, William Halliday, Diane Kitching, Dwayne Lepitzki, Amanda Martin, Karen McLachlan Hamilton, Dave Seburn, Ken Young, and Eleanor Zurbrigg effectively guided the operation of the journal. We are indebted to our very dedicated team.

The following *Associate Editors* managed, assessed, and reviewed manuscripts published in volume 132: R. Brooks, University of Guelph, emeritus, Guelph ON (2 manuscripts); P.M. Catling, Agriculture and Agri-Food Canada, retired, Ottawa ON (6); F. Chapleau, University of Ottawa, Ottawa ON (1); J. Foote, Algoma University, Sault St. Marie ON (4); W. Halliday, University of Victoria, Victoria BC (18); D. Lepitzki, Banff AB (1); D.F. McAlpine, New Brunswick Museum, Saint John NB (1); J. McCracken, Bird Studies Canada, Port Rowan ON (1); G. Mowat, Government of British Columbia, Nelson BC (1); D.W. Nagorsen, Mammalia Biological Consulting, Victoria BC (2); J.M. Saarela, Canadian Museum of Nature, Ottawa ON (1); D. Seburn, Canadian Wildlife Federation, Ottawa ON (6); J. Skevington, Agriculture and Agri-Food Canada, Ottawa ON (1).

As with many other journals, *Associate Editors* are at times having difficulty finding suitable reviewers; without dedicated *Associate Editors* and reviewers there would be no journal. As such, a heart-felt thanks and gratitude is extended to the following who reviewed manuscripts published in volume 132 (number of manuscripts reviewed >1 in parentheses): Carl Anthony, John Carroll University; Andréanne Beardsell, Université du Québec à Rimouski; Christine Bishop, Environment and Climate Change Canada; Sean Blaney, Atlantic Canada Conservation Data Centre (2); Ernie Brodo, Research Associate, Canadian Museum of Nature; Ron Brooks, University of Guelph (2); Dan Brunton, Brunton Consulting (2); Jacob Burkhart, University of Missouri; William Busby, Kansas Biological Survey; Rob Cannings, Royal British Columbia Museum; Pauline Catling, North-South Environmental Inc.; Tony Chubbs, Department of National Defence; Stephen Clayton, New Brunswick Museum; Justin Congdon, University of

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DWAYNE LEPITZKI, *Editor-in-Chief*

AMANDA MARTIN, *Assistant Editor*

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COVER: *Polyergus bicolor*, a slave-making ant, was recently discovered for the first time in Alberta, a substantial range expansion for the species. It was found parasitizing *Formica podzolica*, a new host for the species. See note in this issue by Christine Sosiak *et al.*, pages 309–312. Photo: C. Sosiak, 21 July 2017, near Sylvan Lake, Alberta.

The Canadian Field-Naturalist

Note

A successfully breeding, partially leucistic American Robin (*Turdus migratorius*)

Nina M. Zitani[1,*], Leanne A. Grieves[1], and R. Greg Thorn[1]

[1]Department of Biology, University of Western Ontario, London, Ontario N6A 5B7 Canada
[*]Corresponding author: nzitani@uwo.ca

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Abstract

American Robin (*Turdus migratorius*) is the most abundant and broadly distributed thrush in North America. Both sexes likely engage in mate choice, and there is some evidence of assortative mating based on breast colour in this species. Over two breeding seasons, we documented a case of partial leucism, primarily of the breast feathers, in a male American Robin in London, Ontario, Canada. We report evidence that the leucistic robin was capable of successful breeding. How the fitness of leucistic versus normal robins compares and how leucism influences mate choice in this and other species remain to be explored.

Key words: Ornithology; colouration; leucism; sexual selection; fitness; breeding; American Robin; *Turdus migratorius*

The colouration of birds is a result of light interacting with either the nanostructure of the integument or cellular pigments, and sometimes a combination of the two (Prum 2006). In birds, melanin is the most common pigment. A variety of feather and skin colour is attributable to two forms of melanin, eumelanin (grey to black colours) and phaeomelanin (some yellows and reds, and browns by admixture of eumelanin). The other major source of pigments in birds is carotenoids derived from their diet. Melanins are not derived from food but are produced by animals endogenously. Early in embryonic development, neural crest-derived melanoblasts migrate to the skin and the newly forming feathers. The melanoblasts differentiate into melanocytes and begin synthesizing melanin by the end of the first week of development (Bharti *et al.* 2006; McGraw 2006).

A multitude of mutations can cause white feathers where there should be feathers coloured by pigments, and there is much confusion in the literature and among birders about the correct names for such colour aberrations. We follow van Grouw (2006, 2013), who provided a summary of the most frequently occurring colour aberrations and a much-needed guide to standardize their naming. Leucism is defined as the partial or total lack of both melanins in feathers and skin as a result of the heritable failure of melanoblasts to migrate to the proper area of the body. Melanocytes and the resulting colours are absent in those areas, and the feathers appear white. Birds may be partially leucistic, with only some white feathers, or totally leucistic, with all white feathers. Importantly, melanocytes and eye pigment cells differ in their embryological origin and leucistic birds have normally coloured eyes (Bharti *et al.* 2006; van Grouw 2013).

Wild birds with leucism may face a number of challenges; however, evidence of a detrimental effect of leucism is inconclusive. In one study, the mortality of leucistic young was double that of young with normal plumage (Reese 1980). In another, a leucistic adult was not accepted into a conspecific group (Corrêa *et al.* 2017). In contrast, a leucistic adult was frequently accompanied by conspecifics in another study (Cestari and Vernaschi Vieira da Costa 2007). Several studies report no evidence that leucism affects adult breeding performance (Owen and Skimmings 1992; Forrest and Naveen 2000).

American Robin (*Turdus migratorius*) is North America's largest, most abundant, and widely distributed thrush. Typically, adult male American Robins have deep greyish to dark-brown upper parts, a blackish head, white crescents above and below the eye, white undertail coverts, and, in most eastern populations, white tips on the outer retrices. The under

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parts and breast are a rich rufous colour (Vanderhoff *et al.* 2016; Figure 1a,b). Females appear similar but with a paler grey crown and mantle, more white on the ventrum, and a paler breast (Figure 1a,b). Adult plumages vary little throughout the year; however, males have darker crowns, less white on the ventrum, and darker breasts in spring compared with autumn (Vanderhoff *et al.* 2016).

There is great interest in documenting the behaviour of leucistic birds to further understand the effects of aberrant plumages and the diverse roles plumage colouration plays in the lives of birds. Here we present evidence of a partially leucistic male American Robin successfully breeding on a ~0.2-ha private property in northwest London, Ontario (43.00°N, 81.29°W) during the 2016 and 2017 breeding seasons.

FIGURE 1. American Robin (*Turdus migratorius*). a,b. Male (top) and female specimens showing normal plumage colouration, collected in Strathroy, Ontario, 1932, Western University Zoological Collections: a. dorso-lateral view; b. ventral view. c–e. Partially leucistic male American Robin, London, Ontario: c. 30 June 2016, d. 27 May 2017, e. 5 June 2017. f. American Robin embryo, below nest site of partially leucistic robin, 18 June 2017. Photos: Nina M. Zitani.

Beginning in late spring 2016, a male American Robin with aberrant white feathers and normal eye colouration was observed multiple times. A photo of the robin was taken on 30 June 2016 (Figure 1c). Later in the summer, the leucistic robin was observed mating with a female of normal plumage and subsequently feeding a fledgling on a lawn. In 2017, the leucistic robin was first observed on 23 April. Over the course of the spring, the robin was observed repeatedly, and photos were taken on 27 May 2017 (Figure 1d) and 5 June 2017 (Figure 1e). By early June, the leucistic robin and a mate with normal colouration were observed bringing nest materials into a large, woody climbing hydrangea (*Hydrangea* sp.). On 18 June 2017, a nearly fully developed embryo was found smashed on a rock below the nest site (Figure 1f). Throughout the season, several Brown-headed Cowbirds (*Molothrus ater*) were observed in the area. On 5 August 2017 at 2000, the leucistic robin was observed on a lawn 0.25 m from a vocalizing fledgling. Shortly thereafter, the leucistic robin approached and fed the fledgling. On several occasions, the leucistic robin was observed singing normally.

The plumage colouration of this leucistic robin was as follows: the typically greyish upperparts of the body were mixed with patches of white, particularly on the mantle and lesser, median, and greater coverts. There appeared to be a greater-than-normal proportion of white around the eye and throat. The usually rich rufous breast was heavily marked by white feather patches. The eyes of the robin were black. The lack of colouration in typically pigmented areas that we observed in this bird and normally coloured eyes are characteristic of partial leucism (van Grouw 2006, 2013). Because of the characteristic markings of this bird, we were confident in all cases that our observations were of the same individual (Figure 1c–e).

The occurrence of leucism in natural populations of wild birds rarely exceeds 1% (Bensch *et al.* 2000). Gross (1965) reported that American Robin had the highest rate (8.2%) of "albinism" among North American birds he surveyed; his tally included not only leucism but all forms of pale aberrations. When strictly defined, leucism in American Robin has been reported less often than albinism and melanism (Vanderhoff *et al.* 2016).

Plumage colouration has long been associated with sexual selection (Darwin 1871), with females typically preferring brightly coloured males (e.g., Safran *et al.* 2005), likely because plumage is often condition-dependent (Hamilton and Zuk 1982). Leucistic birds may appear duller or less attractive to prospective mates and, consequently, may have lower reproductive success and overall fitness compared with normally-coloured individuals, especially those with brightly coloured plumage.

In species where the sexes share the same traits (e.g., breast colour in American Robin), mutual sexual selection can occur if both sexes benefit from discriminating among potential mates based on these traits (Rowe and Weatherhead 2011). The partially leucistic male robin we observed had a large proportion (~40–50% of breast area) of white feathers on his breast. To our knowledge, there are no data on how leucism might influence mate preference in American Robin; however, because robins apparently exhibit positive assortative mating with respect to breast colour (Rowe and Weatherhead 2011), we expect this leucistic male would be more likely to mate with a paler female.

In conclusion, our report documents a rare case of partial leucism in American Robin, and provides evidence that leucistic robins are capable of successful breeding. How the fitness of leucistic versus normal robins compares remains to be explored. Given the mixed results in the literature on the impacts of leucism, more studies are needed to understand the maintenance of leucism in natural populations and the impacts of this plumage abnormality on wild birds.

Author Contributions

Writing – Original Draft: N.Z. and L.G.; Writing – Review & Editing: N.Z., L.G., and R.G.T.; Conceptualization: N.Z.; Investigation: N.Z and R.G.T.

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Occurrence of anthropogenic litter in nestling Tree Swallows (*Tachycineta bicolor*)

Stephanie Walsh[1], Jennifer Haughton[2], Lee Bellan[1], Isabelle Gosselin[1], Amy Festarini[1,*], David Lee[1,3], and Marilyne Stuart[1]

[1]Canadian Nuclear Laboratories, Chalk River Laboratories, 286 Plant Road, Chalk River, Ontario K0J 1J0 Canada
[2]Algonquin College, 186 Frank Nighbor Street, Pembroke, Ontario K8A 4M5 Canada
[3]University of Waterloo, Waterloo, Ontario N2L 3G1 Canada
[*]Corresponding author: amy.festarini@cnl.ca

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Abstract

While undertaking a study of the effects of strontium-90 on Tree Swallow (*Tachycineta bicolor*) near Chalk River, Ontario, we noticed the presence of anthropogenic litter (pieces of metal, glass, and plastic, and paper, plastic, and foil wrappers, >1 mm in size) in the nestlings. Although combustible litter (pieces of plastic and wrappers) were not quantified before the nestlings were incinerated in 2014 and 2015, gizzards were dissected in 2016. Litter (>1 mm diameter) was found in 30% of the 74 nestlings examined. This material is most likely provided to nestlings, along with food (insects) and natural grit (sand, stones, and mollusc shells), which we also found, by parent birds; however, it could lead to internal injuries and/or harmful substances being absorbed by the young birds.

Key words: Tree Swallow; *Tachycineta bicolor*; nestling; grit; environmental impact; anthropogenic litter; metal; glass; plastic; paper

Introduction

Insoluble and soluble natural grit (sand, stones, and mollusc shells) is an important component of many avian diets, as it improves the process of grinding foods, such as seeds, plant material, and insects, in the gizzard (Barrentine 1980; Best and Gionfriddo 1991; Gionfriddo and Best 1995). In atricial species, grit is provided by parents. The amount and size of grit consumed by a species is believed to depend on the specific diet of the bird (Gionfriddo and Best 1995). Tree Swallow (*Tachycineta bicolor*), an insectivorous species, requires grit for efficient digestion (Mayoh and Zach 1986), and adults have been found to feed grit to nestlings as young as three days of age (Mayoh and Zach 1986).

If anthropogenic litter (e.g., pieces of metal, glass, and plastic as well as paper, plastic, and foil wrappers) is present near nesting locations, it too could be fed to nestlings. However, ingested anthropogenic litter could lead to internal injury, and/or harmful substances from the materials could be absorbed by the nestlings (Bellrose 1975; Trost 1981; Azzarellow and Van Vleet 1987; Fry *et al.* 1987; Laist 1987; Colabuono *et al.* 2010). Herein, we report on the ingestion of anthropogenic litter by Tree Swallow nestlings near Chalk River, Ontario, Canada.

Methods

In preparation for a strontium-90 (Sr-90) study described in Lee *et al.* (2019), nest boxes were installed on the 4000-ha property of the Canadian Nuclear Laboratories' Chalk River Laboratories (46.052578°N, 77.360890°W; Figure 1) in suitable Tree Swallow nesting habitats (wetland and shoreline; De Steven 1980; Robertson and Rendell 1990). Tree Swallows will readily inhabit nest boxes and tolerate human disturbances, making them an ideal bird for biomonitoring and research (De Steven 1980; Mayoh and Zach 1986; Robertson and Rendell 1990).

Monitoring of the nest boxes began in late April or early May of each year, and observations of nesting, egg laying, clutch size, hatchings, nestling growth, and fledging were documented. When nestlings were 12 days old (as determined from known hatch dates), one nestling from each nest box with at least four young was collected (on average a nest box would contain six nestlings). In all, 74 12-day-old nestlings

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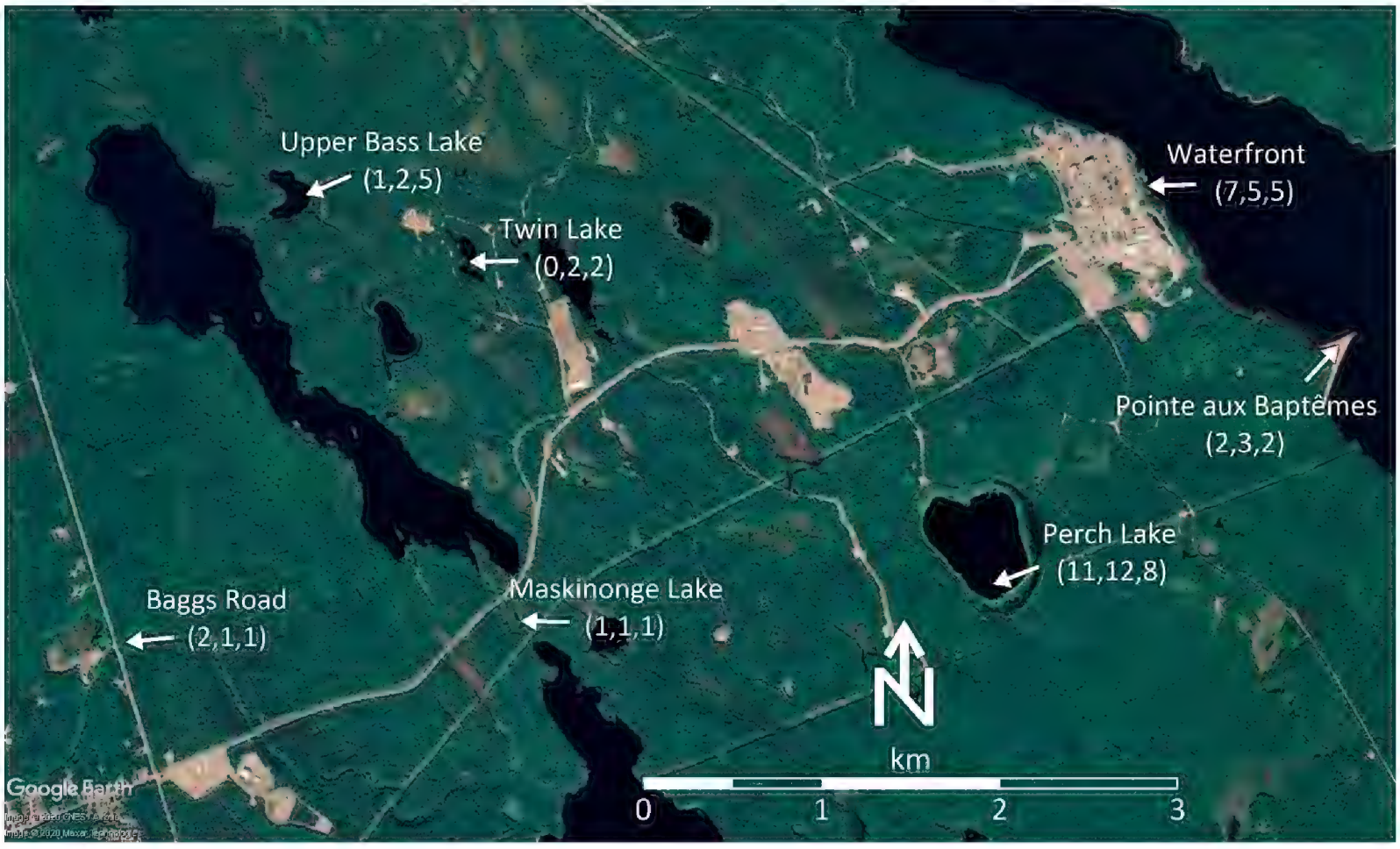

FIGURE 1. Number of Tree Swallow (*Tachycineta bicolor*) nestlings (2014, 2015, 2016) collected at each location on the Canadian Nuclear Laboratories' Chalk River property. Source: Chalk River Laboratories, Chalk River, Ontario, Canada. 46°03′00.2″N, 77°21′51.7″W. Google Earth Imagery date: 20 August 2019. Data providers: DigitalGlobe 2019. Accessed: November 2019.

were taken, euthanized, their external surfaces verified clean, and frozen.

In 2013, carcasses were incinerated for the determination of Sr-90 (Lee *et al.* 2019). Frozen carcasses were thawed overnight in a refrigerator, then dehydrated overnight in an oven, at 105°C. After cooling to room temperature, carcasses were heated to 250°C for 2 h and to 450°C for 16 h, with the 16 h incineration performed a second time to ensure complete ashing. After incineration, samples were cooled to room temperature. The ash was gently milled using a spatula, and any material (i.e., stone, glass, and metal fragments) larger than about 1 mm in diameter was removed. Beginning in 2014, natural grit materials and anthropogenic litter larger than about 1 mm in diameter observed in the ashes were noted and photographed.

In 2016, on thawing of the carcasses, the gizzard contents of each bird were examined visually for materials (e.g., insects, shells, plastic items) that would be incinerated during the ashing process. Observations were noted and the material was returned to the carcass before each carcass was dried and incinerated as above; non-combustible materials larger than about 1 mm in diameter were removed and photographed after the ashing process. Although the general type of litter was noted, pieces were not measured.

Results

In addition to small stones, metal, and/or glass fragments were found in five of 24 nestlings in 2014 and in 10 of 26 nestlings in 2015 (Table 1). Because the gizzards of nestlings collected in 2014 and 2015 were not examined before the nestlings were incinerated, results for combustible materials, such as plastic, are not available. In 2016, the gizzards were examined prior to incineration and we observed flying insects mixed with small stones, sand, grass, and mollusc shells, as well as anthropogenic materials, including pieces of metal and glass, sections of wrappers (most often pieces of shiny cigarette and chewing gum wrappers up to ~1 cm wide) in seven of 24 birds (Table 1). Figures 2 and 3 provide examples of litter collected from nestlings sampled in 2014–2016.

The presence of anthropogenic material in the nestlings occurred most often along the Ottawa River shoreline and around Perch Lake, where human activities are more prominent (Figure 1; Tables 2 and 3). Such material was seldom found in nestlings collected from more remote areas.

In 2016, no significant differences (*t*-test, $t_9 = 1.146$, $P = 0.281$) were found between the weights of 12-day-old nestlings with (average 21.0 g, range 19.5–22.2 g) and without (21.8 g, 20.5–22.8 g) anthropogenic litter in their gizzards.

TABLE 1. Types of litter (>1 mm diameter) found in nestling Tree Swallows (*Tachycineta bicolor*), 2014–2016.

Year	No. nestlings	% nestlings containing fragments			
		Metal	Glass	Wrapper	Plastic
2014	24	12.5	4.2	n/a*	n/a
2015	26	30.8	11.5	n/a	n/a
2016	24	12.5	20.8	4.2	4.2

*n/a = not available because these materials would have been incinerated.

FIGURE 2. Examples of metal turnings found in the whole body ashes of a Tree Swallow (*Tachycineta bicolor*) nestling. Photo: Jennifer Haughton.

FIGURE 3. Examples of glass fragments found in the whole body ashes of a Tree Swallow (*Tachycineta bicolor*) nestling. Photo: Jennifer Haughton.

TABLE 2. Locations of nestling Tree Swallows (*Tachycineta bicolor*) with anthropogenic litter (>1 mm diameter) in their gizzards, 2016.

Location	No. nestlings	No. nestlings containing anthropogenic fragments			
		Metal	Glass	Wrapper	Plastic
Baggs Road	1	0	0	0	0
Maskinonge Lake	1	1	0	0	0
Upper Bass Lake	5	0	1	0	0
Twin Lake	2	0	0	0	0
Perch Lake	8	0	2	0	0
Pointe aux Baptemes	2	1	0	0	1
Waterfront	5	1*	1	1*	0

*Both fragment types were in the same nestling.

TABLE 3. Locations of nestling Tree Swallows (*Tachycineta bicolor*) containing glass and metal pieces (>1 mm diameter) in 2014 and 2015.

Location	No. nestlings	No. nestlings containing anthropogenic fragments	
		Metal	Glass
Baggs Road	3	0	0
Maskinonge Lake	2	0	0
Upper Bass Lake	3	0	0
Twin Lake	2	0	0
Perch Lake	23	4	2
Pointe aux Baptemes	5	3	1
Waterfront	12	4*	1*

*Both fragment types were found in one nestling.

Discussion

Anthropogenic litter was found in 30% of 74 nestling Tree Swallows collected in 2014–2016 near Chalk River, Ontario. We consider this to be an underestimate, because it does not include litter fragments <1 mm in diameter or combustible litter for two of the three years of the study.

Barrentine (1980) reported grit in 80% of Barn Swallow (*Hirundo rustica*) nestlings sampled, providing evidence that grit is an important dietary factor during the growth of swallow nestlings and a cause for concern for birds that nest in areas where grit-like anthropogenic material may be present.

Mayoh and Zach (1986) found that Tree Swallows had a greater percentage of anthropogenic litter in their "stomachs" than did House Wrens (*Troglodytes*

aedon) at the same age. This may be because swallows forage along shorelines and nearby roads (in a ~400 m feeding radius during the nestling period), where greater amounts of anthropogenic litter are generally found. Barrentine (1980) showed that while swallows consumed grit of various colours, sizes, and compositions, they have a clear preference for light-coloured objects between 1 and 3 mm in size. Considering metals are generally light in colour, and glass, plastic, and wrapper materials can also be a light colour, swallows could be intentionally choosing human-made materials over natural grit.

Anthropogenic litter can be domestic or industrial. The presence of metal turnings in Tree Swallow nestlings was a unique finding that is particularly relevant to industrial areas.

The potential detrimental effects of anthropogenic materials on birds are well known. For example, the ingestion of metal pieces by waterfowl can result in lead poisoning (Bellrose 1975; Trost 1981), and the occurrence and impacts of plastic ingestion by bird species, especially marine birds, are prevalent (see for example Provencher *et al.* 2014). Reported adverse health effects include: proventricular impactions, ulcerative lesions (Azzarellow and Van Vleet 1987; Fry *et al.* 1987); digestive tract blockages, stomach lining damage, appetite suppression (Azzarellow and Van Vleet 1987; Laist 1987); exposure to polychlorinated biphenyls and organochlorine pesticides (Colabuono *et al.* 2010); and lowered steroid hormone levels, delayed ovulation, and reproductive failure (Azzarellow and Van Vleet 1987).

We have documented the presence of anthropogenic litter in young Tree Swallows, in an environment previously considered to be relatively litter free. While we observed that the ingestion of litter did not significantly impact the weights of the nestlings, potential risks of ingestion of anthropogenic litter on Tree Swallow nestlings remain to be investigated.

Author Contributions

Writing – Original Draft Preparation: S.W.; Writing – Review & Editing: L.B., A.F., I.G., J.H., D.L., M.S., and S.W.; Methodology: D.L. and M.S.; Investigation: L.B., A.F., I.G., and J.H.; Resources: L.B.; Data analysis: A.F. and I.G.; Visualization: L.B.; Project Administration: M.S.; Supervision: D.L. and M.S.

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Note

First record and new host record of the obligate dulotic ant, *Polyergus bicolor* (Hymenoptera: Formicidae), in Alberta, Canada

Christine E. Sosiak[1,*], Mari West[2], and James R.N. Glasier[3]

[1]Federated Department of Biology, New Jersey Institute of Technology/Rutgers-Newark, Newark, New Jersey 07102 USA
[2]Department of Entomology, University of California Riverside, Riverside, California 92521 USA
[3]Métis Nation of Alberta, Environment Division, Edmonton, Alberta T5G X05 Canada
[*]Corresponding author: ces43@njit.edu

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Abstract

We describe the discovery of *Polyergus bicolor*, an obligate slave-making ant species, as a new provincial record in Alberta. This species was previously known mostly from eastern Canada and the northeastern United States and has been sparsely collected: only once in the past 50 years. *Polyergus bicolor* was discovered parasitizing *Formica podzolica*, which is also a new host for the species. This discovery marks a significant expansion of both range and host for *P. bicolor*.

Key words: *Polyergus bicolor*; dulotic parasitism; range expansion; host expansion; Alberta; *Formica podzolica*

Polyergus (Latreille 1804) is a predominantly holarctic genus of ants that contains 14 species, 11 of which are present in North America (Trager 2013). All *Polyergus* display obligate dulotic behaviour (slave-making), making them a remarkable genus that has received a good deal of research interest.

Colony foundation occurs when a mated *Polyergus* queen enters a *Formica* nest, kills the queen, and usurps her role, with *Formica* workers taking care of her and her brood (Hölldobler and Wilson 1990). To maintain *Formica* worker populations in the colony, *Polyergus* workers locate a host nest, and then raid it for pupae, prepupae, and occasionally last-instar larvae. When the *Formica* pupae mature to adults in the *Polyergus* nest, they accept that nest as their own, and perform the majority of tasks within the colony (Trager 2013). Host *Formica* species vary, depending on the *Polyergus* species: some *Polyergus* will parasitize only one *Formica* species, while others are capable of parasitizing multiple species. Generally, the host species is from the *Formica fusca* group or the *Formica pallidefulva* group (Trager 2013).

In western North America, *Polyergus* is overwhelmingly represented by *Polyergus mexicanus* (Trager 2013; Glasier *et al.* 2016); in Idaho, *P. breviceps* is also present (Wheeler 1917; Smith 1947; Trager 2013). (Note: there are generally no accepted common names for ants.) *Polyergus bicolor* was previously reported as restricted to eastern North America: Ontario to Illinois (Smith 1947; Wheeler 1968; Trager 2013). It was reported as far west as Saskatchewan and Montana by Wheeler (1917) as *Polyergus rufescens bicolor*. It was only confirmed as far west as the Dakotas by Trager (2013), who raised it to the status of species. Trager noted that he was unable to collect any *P. bicolor* during the course of his study within its historical range, save for one collection made in Wisconsin. In the last 50 years, he had found no *P. bicolor* collection records from its historical range (Trager 2013).

We first found *P. bicolor* in Alberta in summer 2017. We collected two colonies in Jarvis Bay Provincial Park, on Sylvan Lake, while collecting and observing *Formica* colony behaviour. Jarvis Bay Provincial Park is a drywood boreal forest characterized by mostly deciduous stands dominated by Trembling Aspen (*Populus tremuloides* Michaux), Balsam Poplar (*Populus balsamifera* L.), Black Spruce (*Picea mariana* (Miller) Britton, Sterns and Poggenburgh), and White Spruce (*Picea glauca* (Moench) Voss); prior records of *P. bicolor* note that it nests mostly in mesic forest, generally in rotten

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stumps or fallen logs, thus habitat similar to Jarvis Bay (Trager 2013).

The specimens were collected by hand around the provincial park campsite after mistaking them for a species of the *Formica rufa* or *Formica sanguinea* species groups. They were found in domed dirt and debris mounds with the host species *Formica podzolica*, identified using published keys (Francoeur 1973; Glasier *et al.* 2013). Our *Polyergus* specimens were identified using Trager's revised key to global *Polyergus* species (Trager 2013). They differ from *P. mexicanus*, the other known *Polyergus* species in the area, by the degree of dark colouration on the abdomen and a complete lack of pilosity on both the vertex of the petiole and the pronotum (Glasier *et al.* 2013; Trager 2013).

A second collection occurred in July 2018 near Hay Lakes, Alberta, an area dominated by mixed deciduous woodlands (Trembling Aspen and Balsam Poplar) similar to Sylvan Lake. They were collected from a rounded mound within a grass meadow and were also using *F. podzolica* as a host. *Polyergus bicolor* has been formally recorded parasitizing both *Formica neorufibarbis* and *Formica subaenescens*, but not *F. podzolica*. The mounds in which we found *P. bicolor* were unlike their normal reported nesting sites, but this could be the result of their using a different host species.

This discovery represents a significant expansion of *P. bicolor*'s previously known range, although it supports Wheeler's (1917) reports of *P. bicolor* in Saskatchewan as *P. r. bicolor*. Although the habitat where we found *P. bicolor* in Alberta is similar to the type of habitat from which it was previously known, the climate of Alberta is distinct from that of southern Ontario and the northeastern United States. The expansion of host species to include *F. podzolica* is also notable; *Polyergus* may use one or several hosts species but tends to show high fidelity to one host for a given population. Within a *Polyergus* species, if different populations are using different hosts, they are often highly specialized to their own host species. Populations show distinct chemical and genetic divergence from one another, perhaps reflecting incipient speciation (Torres *et al.* 2018). Because newly mated *Polyergus* queens typically stay with the host species of their parent colony, this fidelity is passed down from generation to generation (Hölldobler and Wilson 1990). *Formica podzolica* is widespread throughout North America and its range overlaps with that of *P. bicolor* in the northeastern United States (Wheeler and Kannowski 1994; Ellison *et al.* 2007); thus, it is difficult to say where host expansion took place. Further genetic work would shed light on potential divergence between *P. bicolor* populations in western and eastern North America, contingent on their host species.

Voucher specimens

Canada, Alberta: Sylvan Lake Jarvis Bay, 52.347°N, 114.091°W and 52.345°N, 114.089°W, hand collected, 21 July 2017, C. Sosiak (Figure 1, personal collections of Christine Sosiak and Mari West).

Canada, Alberta: 4 km SE of Hay Lakes, Aspen Parkland, 53.165°N, 113.014°W, hand collected, with *F. podzolica,* 27 July 2018, J.R.N. Glasier (Strickland Museum and personal collection of J.R.N. Glasier). Strickland Museum accession numbers: *P. bicolor* specimens UASM396245, UASM396246; *F. podzolica* specimens UASM396247, UASM396248.

Author Contributions

Writing – Original Draft: C.E.S.; Writing – Review & Editing: C.E.S., M.W., and J.R.N.G.; Species Collection: C.E.S., M.W., and J.R.N.G.; Species Identification: C.E.S. and J.R.N.G.; Funding Acquisition: M.W.

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FIGURE 1. Lateral a. and frontal b. views of a *Polyergus bicolor* specimen collected in Jarvis Bay Provincial Park, Sylvan Lake. Photos: Christine Sosiak.

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Tall grass prairie ecosystem management—a gastropod perspective

Annegret Nicolai[1,2,*], Robert G. Forsyth[3], Melissa Grantham[4], and Cary D. Hamel[4]

[1]Université Rennes, UMR CNRS 6553 EcoBio, Station Biologique Paimpont, Paimpont 35380 France
[2]Western University, Department of Biology, 1151 Richmond Street North, London, Ontario N6A 5B7 Canada
[3]New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[4]Nature Conservancy of Canada, Manitoba Region, Suite 200 - 611 Corydon Avenue, Winnipeg, Manitoba R3L 0P3 Canada
[*]Corresponding author: annegret.nicolai@univ-rennes1.fr

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Abstract

Less than 5% of the original tall grass prairie in North America remains. A portion of this remnant, composed of wetland, grassland and forest, is protected by the Nature Conservancy of Canada (NCC) in southern Manitoba. This heterogeneous ecosystem has rich biodiversity; however, gastropods have not been surveyed in Canada's tall grass prairie. We studied gastropods in Prairie, Wet Meadow, Forest, and Wet Forest habitats of the Manitoba Tall Grass Prairie Preserve that vary with respect to land management practices (prescribed burning, grazing by cattle). Gastropod community composition was unique in the Prairie where mounds of grass litter form permanently moist cavities harbouring aquatic species, while dry-habitat species colonized the upper parts of these mounds. Gastropod communities in Prairie habitats were negatively affected by grazing and burning that occurred in the five years prior to our survey. Unburned Forest patches included both forest gastropod species and edge effect influenced open-habitat species and harboured the most diverse gastropod communities. These unburned Forest patches potentially provide a species pool for post-burn prairie recolonization. The gastropod community of Wet Meadows was not affected by grazing and was composed mainly of aquatic species. In this gastropod survey five species were recorded from Manitoba for the first time. The rare Blade Vertigo (*Vertigo milium*) is also reported.

Key words: Fire; grazing; freshwater snails; terrestrial snails and slugs; protected area; rare species; Manitoba

Introduction

Tall grass prairie once covered 68 million ha of North America before conversion to urban areas or cropland in the United States and Canada—less than 5% remains (Sampson and Knopf 1994). Tall grass prairie harbours a diversity of terrestrial and aquatic plants and animals within a mosaic of grassland, pothole-forming wetland/grassland systems, and shrubby/wooded areas. Ecosystem services that include nutrient cycling, water retention, aquifer recharge, the storage of atmospheric carbon, as well as enhanced water infiltration and improved runoff water quality are all of great ecological and economic importance (Glaser 2012). As a result of human activity, prairies are the most highly impacted of any of the continent's terrestrial ecosystems. Current threats to the biodiversity and ecological functioning of the remaining tall grass prairie include: habitat fragmentation, loss by conversion to cropland, incompatible grazing practices, undesirable habitat changes due to fire and fire exclusion, spread of invasive plant species, and stream degradation due to incompatible land management practices and soil erosion (Glaser 2012).

The biodiversity of northern tall grass prairie has been poorly explored, especially that of soil related functional animal groups, such as terrestrial gastropods. Terrestrial gastropods are generally under-surveyed in most of Canada and are usually absent from management strategies for protected areas. Being a significant component of biodiversity among ground dwelling species, terrestrial gastropods are globally declining (Lydeard *et al.* 2004) and play a crucial role in ecological processes (Jordan and Black 2012) by aiding in decomposition, nutrient cycling and soil building processes, and by providing food and essential nutrients to wildlife. Also, terrestrial gastropod abundance and diversity can be used as ecological indicators at the litter-soil interface, such as for logging practice management in forests (British Columbia Ministry of Forests 2008). Previously, only a few terrestrial gastropod surveys have occurred in Manitoba, e.g., by the Manitoba Museum and by Nekola (2005), and none of these targetted the community in the tall grass prairie.

Humans have long used fire to influence North American ecosystems, including First Nations who

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used fire to create large areas of grassland in the Great Plains regions (Pyne 1983; Botkin 1990). While First Nations used fire to promote a habitat mosaic and a resource diversity that provided greater stability to their lives, later European settlers used burns to create uniformity in ecosystems (Lewis 1985). Prescribed fire has become an important management tool for prairie and forest conservation in North America (Gottesfeld 1994; Williams 2000), and is used to limit the spread of invasive plants (Brooks and Lusk 2008), promote growth and reproduction in native prairie vegetation (Towne and Owensby 1984), and improve and expand habitat for grassland and parkland birds (e.g., Burkman 1993; Madden *et al.* 1999; Davis *et al.* 2000; Ludwick and Murphy 2006; Vierling and Lentile 2006; Buehler *et al.* 2007; Grant *et al.* 2010; Klaus *et al.* 2010; Austin and Buhl 2013) and rare prairie plants (e.g., Becker 1989; Bleho *et al.* 2015). Some authors have expressed concern about the detrimental impacts of prescribed burns on prairie that include providing optimal germinating conditions for invasive plant seedlings by opening the vegetation canopy (Ohrtman *et al.* 2011), and negative direct and indirect effects on the abundance of small mammals (Kaufman *et al.* 1990), birds (Reinking 2005), arthropods (Swengel 1996; Harper *et al.* 2000), and terrestrial gastropods (Nekola 2002; reviewed by Saestedt and Ramundo 1990; Knapp *et al.* 2009).

In addition to structural modification by fire, tall grass prairie has also been intermittently grazed by large ungulates, i.e., Bison (*Bison bison*; Knapp *et al.* 1999). Domestic Cattle (*Bos taurus*) are now the dominant grazers at most prairie sites. Grazing can enhance plant diversity by encouraging the growth of some prairie species (Damhoureyeh and Hartnett 1997, 2002). The effect on prairie fauna is also selective; birds (Sliwinski 2012 as cited in Glaser 2012), arthropods (van Klink *et al.* 2015), and terrestrial gastropods (Baur *et al.* 2007) respond differently to grazing regimes, defined by stocking rate, grazing frequency, and livestock type.

One of the largest remaining tall grass prairie complexes in Manitoba is protected by the Nature Conservancy of Canada (NCC) and partners as part of the Manitoba Tall Grass Prairie Preserve (MTGPP). As part of an effort to preserve tall grass prairie biodiversity and the ecosystem services it provides, managers need to understand how management practices influence the gastropod community in the MTGPP. Currently, the NCC uses rotational prescribed burning and grazing by cattle to maintain a spatial and structural mosaic of grassland, wetland, and forest within the tall grass prairie system. For managers of protected prairie habitat, such as the NCC, the question of which management strategy to apply remains an ongoing challenge. The goal is to identify the appropriate regime of prescribed burns and grazing required to maintain a generally rich floral and faunal diversity without negatively affecting the diversity of functional groups, such as gastropods involved in litter-soil processes, or those of conservation concern. To assess the impact of current management practices on the composition of the gastropod community in the MTGPP a gastropod survey was undertaken at variously managed sites (burning or grazing within the past five years) within the preserve.

Study Area

The 4100 ha MTGPP is located in the rural municipality of Stuartburn, in southeastern Manitoba, Canada (Figure 1). The majority (>70%) of MTGPP lands are owned by the NCC; the Manitoba Habitat Heritage Corporation and Nature Manitoba own the remainder. Preserve lands are jointly managed through a Management Committee that includes landowners as well as Manitoba Sustainable Development and Environment and Climate Change Canada. The preserve is comprised of dozens of distinct management units, allowing temporal and spatial variation in management practices.

The habitats comprise two grassland types (Prairie and Wet Meadow) and two woodland patches (Forest and Wet Forest). The two woodland types range from small groves to larger forest areas and provide mostly edge habitat, but also include humid microhabitats under logs and drier microhabitats on the surface of logs and on branches. The habitat types (classification based on Minnesota Department of Natural Resources 2005) differ in vegetation composition and structure as well as in seasonal cycle of flooding as follows:

Prairie (P)

Tall grass prairie communities dominated by tall and mid-height graminoid species up to 1.50 m tall. Big Bluestem (*Andropogon gerardi* Vitman), Prairie Dropseed (*Sporobolus heterolepis* (A. Gray) A. Gray), Little Bluestem (*Schizachyrium scoparium* (Michaux) Nash), Yellow Indiangrass (*Sorghastrum nutans* (L.) Nash), and Plains Porcupine Grass (*Hesperostipa spartea* (Trinius) Barkworth) are most common. Not flooded but forming very humid microhabitats of roots and decaying grass leaves in the upper soil layer between mounds of grass.

Wet Meadow (WM)

Meadow dominated by graminoid species up to 0.50 m tall. Broad-leaved species such as Slim-stemmed Reedgrass (*Calamagrostis stricta* (Timm) Koeler), Prairie Cordgrass (*Sporobolus michauxianus* (Hitchcock) P.M. Peterson & Saarela), Sartwell's Sedge (*Carex sartwellii* Dewey), and Woolly Sedge

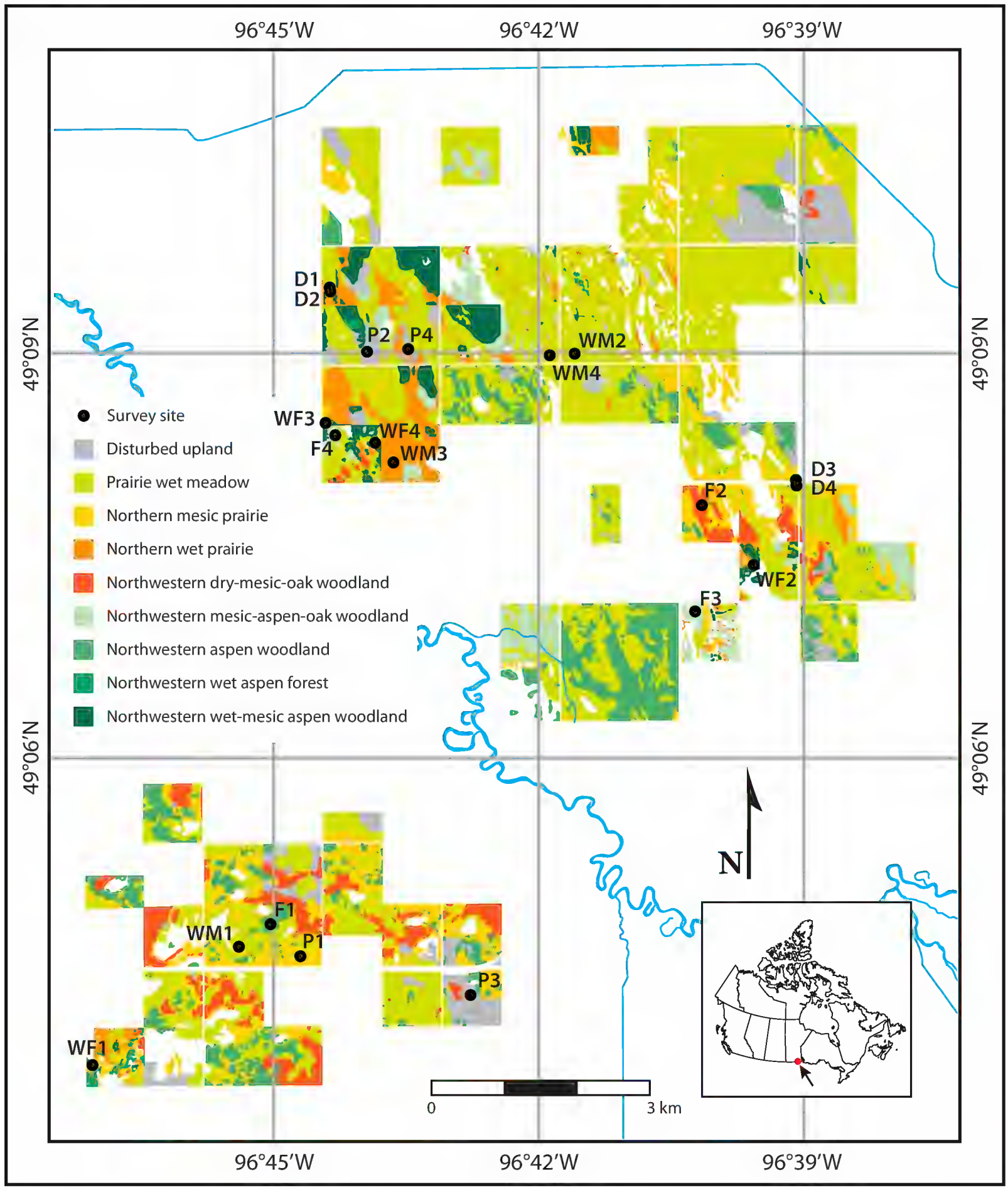

FIGURE 1. Phytosociology classification in the Manitoba Tall Grass Prairie Preserve and gastropod survey sites: F = Forest, WF = Wet Forest, P = Prairie, WM = Wet Meadow. Two drainage sites have also been analyzed, D1/D2 and D3/D4, with sampling points on each side of the road.

(*Carex pellita* Muhlenberg ex Willdenow) are typical, with Tussock Sedge (*Carex stricta* Lamarck) an occasional dominant. Habitat is subjected to moderate inundation by standing water following spring thaw and heavy rains, and to periodic drawdowns during the summer.

Forest (F)

Forest patches within the grassland that are not flooded and are dominated by trees and herbaceous species. Herbaceous plant cover commonly includes: Wild Lily-of-the-valley (*Maianthemum canadense* Desfontaines), Northern Bedstraw (*Galium boreale*

L.), Wild Sarsaparilla (*Aralia nudicaulis* L.), American Vetch (*Vicia americana* Muhlenberg ex Willdenow), and Lindley's Aster (*Symphyotrichum ciliolatum* (Lindley) Á. Löve & D. Löve). Bur Oak (*Quercus macrocarpa* Michaux) and Trembling Aspen (*Populus tremuloides* Michaux) are dominant tree species.

Wet Forest (WF)

Forest patches dominated by trees and herbaceous species that are subjected to the same inundation regime as Wet Meadow sites. Herbaceous cover commonly includes: Star-flowered False Solomon's Seal (*Maianthemum stellatum* (L.) Link), Wild Strawberry (*Fragaria virginiana* Miller), Northern Bedstraw (*G. boreale*), Calico Aster (*Symphyotrichum lateriflorum* (L.) Á. Löve & D. Löve), and Dwarf Raspberry (*Rubus pubescens* Rafinesque). Trembling Aspen (*Populus tremuloides*), Balsam Poplar (*Populus balsamifera* L.), or Black Ash (*Fraxinus nigra* Marshall) are the most important tree species.

Historical and recent fire and grazing management on MTGPP property is highly diverse; there is no specific information on the historical frequency of grazing or burning for this area. Long-term management plans include prescribed burns once every five years, typically in spring or fall. In the year prior to prescribed fire, properties are not grazed. However, the interval between fires can be variable due to occasional wildfires and seasonal weather conditions not conducive to the use of prescribed fire (Bleho *et al.* 2015). A twice-over rotational grazing system is used at the MTGPP but is individually managed by cattle owners. Information on frequency and intensity of grazing and fire was not available. Timing of fire and grazing (Table 1) was based on best available information.

Sites within historically human-built drains are also part of the MTGPP ecosystem, and potentially could serve as a source for post-management recolonization by gastropods. Drainage wells were therefore also investigated for richness and abundance of aquatic gastropods that might be available to colonize wet and flooded grassland or forest habitat.

Methods

All sites (n = 16) examined within the MTGPP had been managed either by burning or grazing (exclusively cattle) within the last five years (n = 10) or had received no active management over the past five years or more (n = 6). Although we were able to sample recently managed (<5 years) and unmanaged (≥5 years) sites for both woodland and grassland habitat types, we were unable to find any Wet Forest that had been subject to both grazing and burning in the previous five years (Table 1).

In September 2013, a visual search and hand collection of gastropods occurred in the litter and the uppermost soil layer using six 0.2 × 0.2 m plots per site (Figure 1). The plots were separated by a distance of at least 20 m on a random, non-linear transect to sample different microhabitats within the same vegetation zone (= site). Additionally, four drainage-well sites of 10 × 10 m were searched during 30 min each for aquatic gastropod species to establish the full gastropod species list in the MTGPP.

Gastropods were identified by A.N. and R.G.F. Vouchers of all species have been deposited in the Manitoba Museum (Catalogue numbers: MM65991 to MM65999 and MM66178 to MM66311). Live gastropods were stored as wet samples at the Biodiversity Institute of Ontario (BIO), Guelph, Ontario, and incorporated into the BOLD database under field sample numbers ANi039 to ANi056 and under the BIO collection numbers BIOUG09921-C08 to -C09 and BIOUG09922-B10, -C02, -C05 to -C07, -C10 to -C12, -D01 to -D07, -E01, -E03 to -E12, and -F02. Individuals of each species were counted to determine abundance/m^2 for each site.

Due to the diversity of management combinations, it was not possible to assemble a set of replicates, so we used an exploratory approach in our multivariate analysis. Species richness was compared among habitat types using an adjusted t-test (Welch) and one-way analysis of variance (ANOVA). The gastropod community composition was analysed with nonmetric multidimensional scaling (NMDS) with Euclidean distance similarity coefficient applied to

TABLE 1. Management history of the sites in the Tall Grass Prairie Preserve, Manitoba, prior to the 2013 sampling year. Information about grazing was available since 1993 and about fire since 1992. F = Forest, WF = Wet Forest, P = Prairie, WM = Wet Meadow.

Habitat	Sites	Years since last grazing	Years since last fire
Woodland	F1	5	2
	F2	1	10
	F3	<20	<21
	F4	<20	<21
	WF1	<20	2
	WF2	1	<21
	WF3	<20	<21
	WF4	<20	<21
Grassland	P1	5	2
	P2	2	<21
	P3	5	<21
	P4	<20	<21
	WM1	5	2
	WM2	1	<21
	WM3	<20	<21
	WM4	<20	7

abundance data (N/m^2) based on the normalized minimal threshold density (Legendre and Legendre 2007; Ramette 2007). The stress coefficient indicates the badness-of-fit, this is the quality of the NMDS ($S < 0.10$: good). Mann-Whitney and Kruskal-Wallis tests were used on scores of the axes to analyse gastropod community differences between habitat types. Hierarchical clustering was performed with the centroid method on a Euclidean distance matrix calculated on the abundance of gastropods (N/m^2). Approximately unbiased *P*-values were computed by multiscale bootstrap resampling, $n = 1000$ (Shimodaira 2004). Spatial autocorrelation of community composition was analysed with the Mantel test using Euclidean distance and $n = 1000$ permutations. Moran's I was calculated for species richness on an inverse distance matrix. All analyses were conducted with the software R 2.8.0 (R Core Team 2008).

Results

The forest and grassland communities formed by terrestrial and aquatic species are distinguishable on the NMDS model (Figure 2) by scores on the first axis (Mann-Whitney, $W = 55$, $n = 16$, $P = 0.01$) and on the third axis (Mann-Whitney, $W = 53$, $n = 16$, $P = 0.03$), but not on the second axis (Mann-Whitney, $W = 41$, $n = 16$, $P = 0.38$). Species richness (Table 2) did not differ between forest and grassland communities (*t*-test, $t_{11.93} = 0.88$, $P = 0.39$). Likewise, species composition (measured as scores on the three NMDS axes; Figure 2) and species richness (Table 2) were not significantly different among Forest, Wet Forest (forest communities), Prairie and Wet Meadow (grassland communities; axis 1: Kruskal-Wallis, $\chi^2_3 = 6.9$, $P = 0.07$; axis 2: Kruskal-Wallis, $\chi^2_3 = 1.3$, $P = 0.73$; axis 3: Kruskal-Wallis, $\chi^2_3 = 5.1$, $P = 0.16$; species richness: ANOVA, $F_{1,12} = 0.27$, $P = 0.84$). Nevertheless, nine of 23 gastropod species showed habitat preference based on presence in a single habitat type (Table 2). Among aquatic gastropods, six of nine species are characterized as vernal species (Clarke 1981), being generally restricted to periodically flooded terrestrial habitats (Table 2). Only two of the vernal species were absent from the drainage well sites (with permanent water). Some typically open-habitat species, such as Costate Vallonia (*Vallonia costata* (O.F. Müller, 1774)) and Trumpet Vallonia (*Vallonia parvula* Sterki, 1893), were only observed at the forest edge. Glossy Pillar (*Cochlicopa lubrica* (O.F. Müller, 1774)), Small Spot (*Punctum minutissimum* (I. Lea, 1841)), and *V. parvula* were only found in the dry, unflooded, Forest, while Tapered Vertigo (*Vertigo elatior* Sterki, 1894), a species preferring very wet habitats (Nekola and Coles 2010), only occurred in the Wet Forest. Blade Vertigo (*Vertigo milium* (Gould, 1840)), a wet grassland species (Nekola and Coles 2010), was only recorded in Prairie sites while Multirib Vallonia (*Vallonia gracilicosta* Reinhardt, 1883) occurred only in Wet Meadow. Marsh Hive (*Euconulus* cf. *praticola* (Reinhardt, 1883); = *E. alderi* (Gray, 1840), see Forsyth and Oldham 2016), also a wet grassland species (Forsyth 2004, 2005), occurred in both grassland habitats.

The cluster analysis of the gastropod community composition (Figure 3) based on the distances in the NMDS model (Figure 2) showed three distinctive clusters (cluster P3-P4, cluster WM2-WM4, and a cluster including the remaining sites) that were not explained by spatial autocorrelation (Mantel test, $z = -0.03$, $P = 0.50$). Moreover, species richness was not spatially autocorrelated (Moran test, $I_{obs} = -0.16$, $I_{exp} = -0.07$, SD = 0.11, $P = 0.38$). This result indicated that management practices may influence gastropod community composition in some habitats. While, two recently managed Prairie sites, P1 and P2, were not significantly different from most sites (Figures 3 and 4a), P3 and P4, left unmanaged for at least five years, had a unique community composition characterized by high abundance of aquatic species (Figures 3 and 4a). P3 and P4 had deep litter filled holes between mounds of grass, whereas recently burned

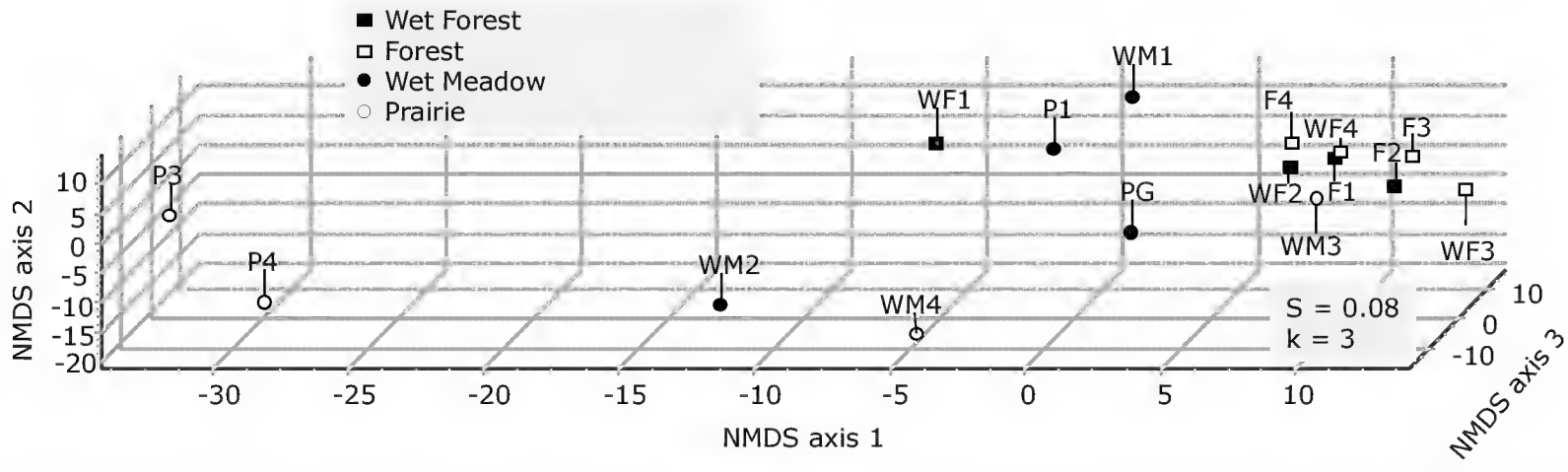

FIGURE 2. NMDS plot of gastropod communities in different habitats occurring in the Tall Grass Prairie. S indicates the stress and k the total number of axes used in the analysis. F = Forest, WF = Wet Forest, P = Prairie, WM = Wet Meadow.

TABLE 2. Frequency and abundance of gastropods in different habitats in the Tall Grass Prairie Preserve, Manitoba (frequency / minimal-maximal abundance per m^2 in four sites per habitat). Species richness is indicated as mean ± SE.

Family	Species	Woodland		Grassland		Drainage
		Forest	Wet Forest	Prairie	Wet Meadow	
Terrestrial gastropods						
Agriolimacidae	*Deroceras laeve*, Meadow Slug	4/3–5	4/3–5	1/3		
Cochlicopidae	*Cochlicopa lubrica*, Glossy Pillar	1/3				
Discidae	*Discus whitneyi*, Forest Disc	3/3–5	2/3–8			
Euconulidae	*Euconulus fulvus*, Brown Hive		1/8			
	Euconulus polygyratus, Fat Hive	2/3–8	3/5–11	2/3–24	3/5–21	2/2–3
	Euconulus cf. *praticola*, Marsh Hive			1/3	1/24	
Gastrodontidae	*Nesovitrea electrina*, Amber Glass	3/8–16	4/3–16	3/13–37	4/8–32	
	Striatura milium, Fine-ribbed Striate		1/3			
	Zonitoides arboreus, Quick Gloss	4/5–19	2/21–27	1/3	3/3–5	
Punctidae	*Punctum minutissimum*, Small Spot	1/3				
Pristilomatidae	*Hawaiia minuscula*, Minute Gem			2/5–11	1/13	
Succineidae	*Mediappendix* cf. *vermeta*, Suboval Ambersnail	1/3	2/3–5	2/3–11	2/5–16	1/3
	Novisuccinea ovalis, Oval Ambersnail	2/5–11	2/3–16		1/11	
	Oxyloma sp., an ambersnail		1/13	1/16		3/3–5
Valloniidae	*Vallonia costata*, Costate Vallonia		1/3			
	Vallonia gracilicosta, Multirib Vallonia				1/3	
	Vallonia parvula, Trumpet Vallonia	1/3				
	Vallonia pulchella, Lovely Vallonia	1/3		2/3–8	1/27	
Vertiginidae	*Gastrocopta tappaniana*, White Snaggletooth			1/5	1/8	
	Vertigo elatior, Tapered Vertigo		1/3			
	Vertigo milium, Blade Vertigo			1/3		
	Vertigo ovata, Ovate Ambersnail			1/3	1/8	
Vitrinidae	*Vitrina angelicae*, Eastern Glass-snail	2/5–6	1/3			
Aquatic gastropods						
Lymnaeidae	*Galba* sp., a fossaria			4/13–104	3/5–53	2/8–9
	Stagnicola elodes, Marsh Pondsnail	1/8	1/16		3/3–11	4/3–24
Planorbidae	*Gyraulus circumstriatus*, Disc Gyro					1/24
	Gyraulus parvus, Ash Gyro			3/3–32	2/8–13	
	Planorbella subcrenata, Rough Ramshorn				1/8	
	Planorbella trivolvis, Marsh Ramshorn					1/5
	Promenetus umbilicatellus, Umbilicate Sprite	1/8	1/3	3/8–19	2/48–59	4/8–27
Physidae	*Aplexa elongata*, Lance Aplexa	1/3	4/3–56	3/5–48	3/5–45	4/19–61
	Physella gyrina, Tadpole Physa					2/8–21
Species richness		7.0 ± 1.3	7.3 ± 1.3	7.8 ± 1.0	8.3 ± 0.5	6.0 ± 1.1

Prairie (P1, Table 1) had bare soil between small grass mounds over most of the habitat. A recently grazed Prairie (P2, Table 1) had smaller grass mounds and less litter than unmanaged Prairie, but the structure of the vegetation and the grass litter were not quantified. Although P1 and P2 had been managed within the past two years prior to our study, their gastropod community composition was similar to those of Forest and Wet Forest. In the Wet Meadow, the recently grazed (WM2) and unmanaged WM4 formed a cluster distinct from the remaining sites (Figures 2 and 3). WM2 and WM4, sites separated only by a small gravel road, had a higher abundance of aquatic species (Figure 5a) relative to other Wet Meadow sites (WM1 and WM3, Figure 5b).

Discussion

The prairie ecosystem is a patchy assemblage of grassland, groves, and small forests. In general, the different habitats are moist due to periodic flooding, especially in the Wet Forest and Wet Meadow. Species richness and gastropod community composition are driven by climate parameters such as water balance at a large sub-continental scale (Horsák and Chytry 2014) and by soil moisture, temperature, and calcium-content at a local scale (Dvořáková and

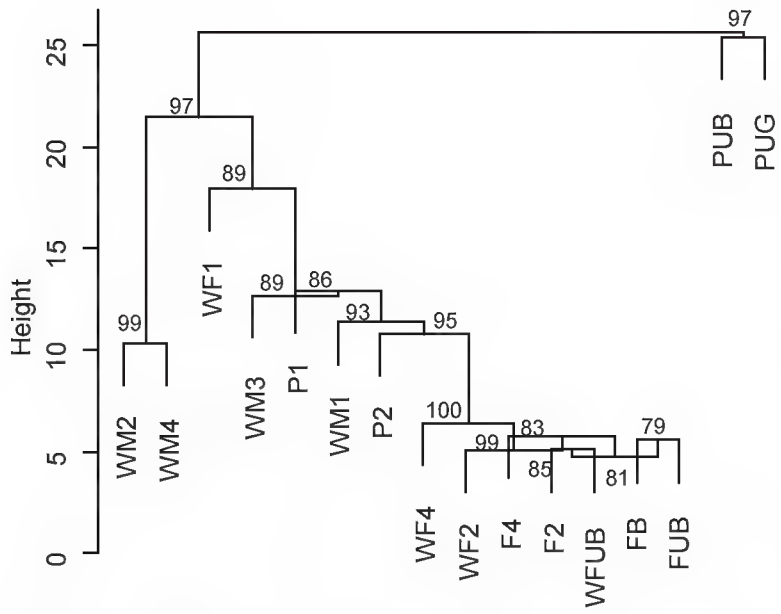

FIGURE 3. Dendrogram of gastropod community clusters in different habitats occurring in the Tall Grass Prairie. Approximately unbiased *P*-value computed by multiscale bootstrap resampling ($n = 1000$) are indicated on the branches. F = Forest, WF = Wet Forest, P = Prairie, WM = Wet Meadow.

Horsák 2012; Hettenbergerová *et al.* 2013). Because of the small size of the forest patches, most of the forested habitat includes forest edges that are suitable for open land species. Therefore, community composition in general is very similar for most grassland and woodland sites. However, the Prairie sites, when undisturbed by human activity, host a very particular gastropod community, characterized by the presence of vernal species, such as Lance Aplexa (*Aplexa elongata* (Say, 1821)) and Umbilicate Sprite (*Promenetus umbilicatellus* (Cockerell, 1887)), and the presence of dry-habitat species, such as Lovely Vallonia (*Vallonia pulchella* (O.F. Müller, 1774)) and *V. gracilicosta*. Dead vegetation accumulates in prairie habitat over years to form mounds of grass litter. Within these mounds, cavities retain water permanently. This permanent water availability allows aquatic species to colonize the cavities within mounds of grass litter, while upper parts of the mounds are exposed to drying and are suitable for dry-habitat species. Burning

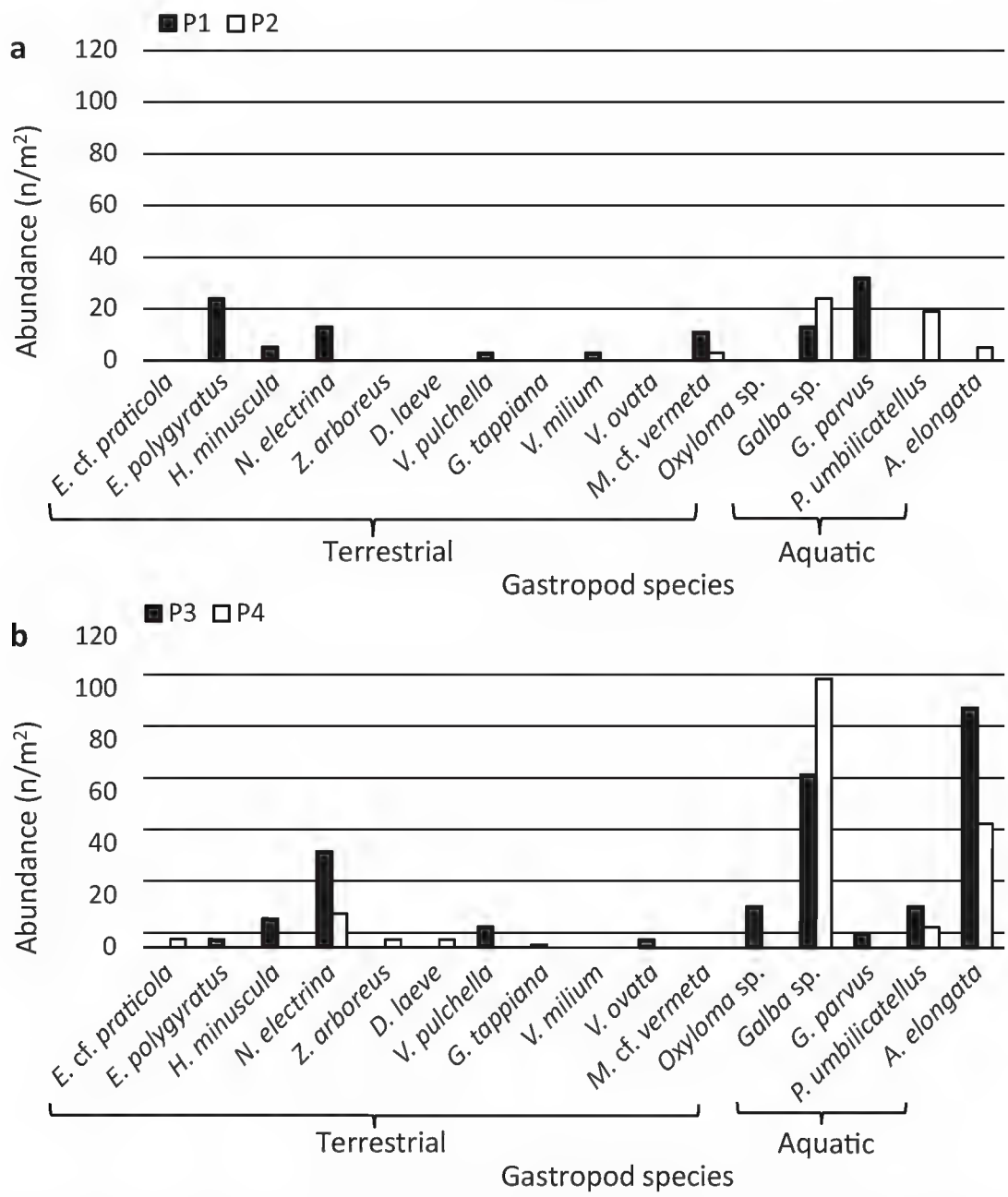

FIGURE 4. Abundance of gastropod species in a. recently burned (P1) and grazed (P2) Prairies, and in b. Prairies where the last management was at least five years ago, in the Tall Grass Prairie Preserve in Manitoba. P3 and P4 form a distinct cluster in the NMDS model (see Figures 2 and 3). Pooled species richness for P1 and P2 is six terrestrial and four aquatic gastropod species, and for P3 and P4 is 10 terrestrial and four aquatic gastropod species. See Table 2 for full species names.

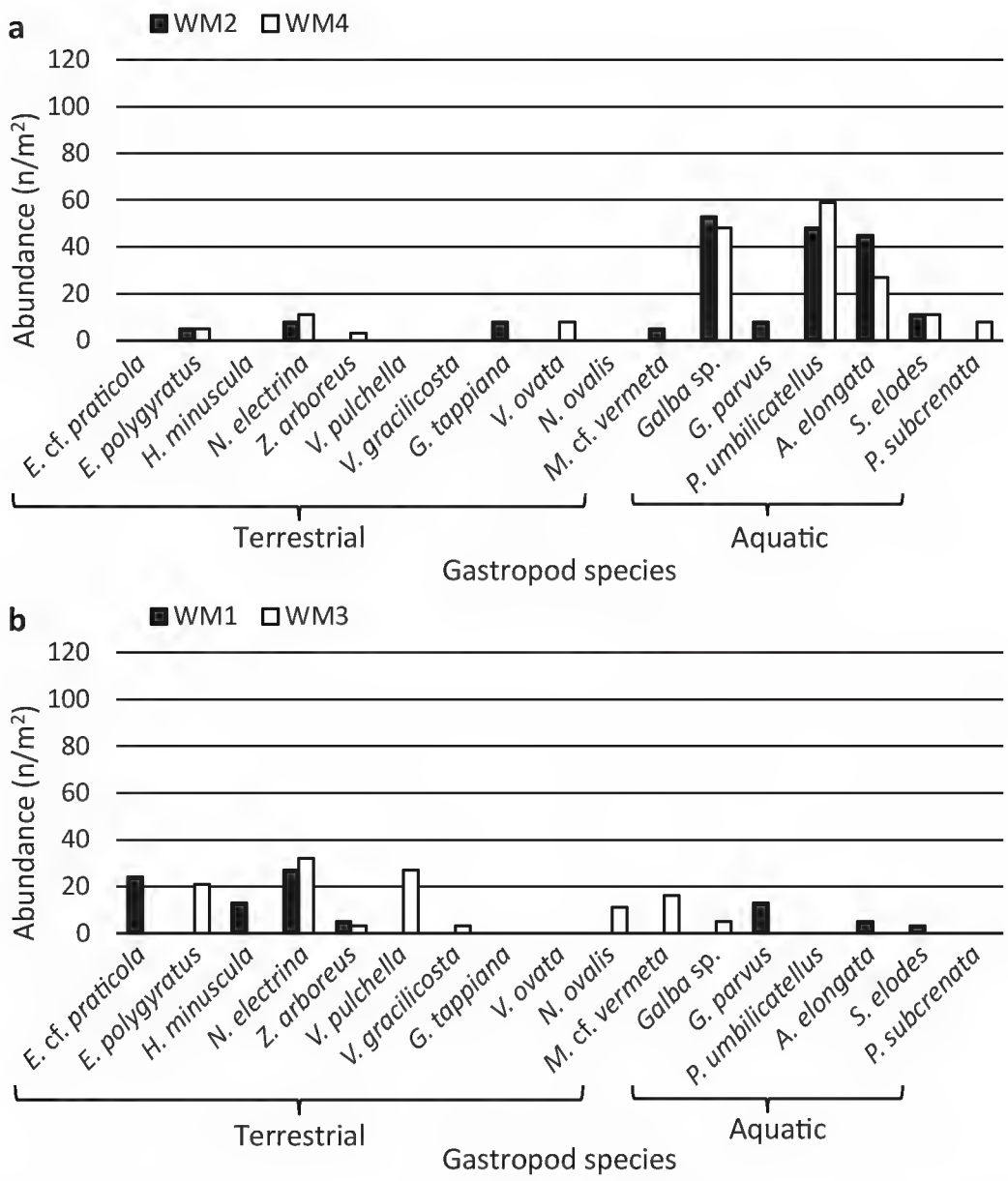

FIGURE 5. Abundance of gastropod species in a. recently grazed Wet Meadow (WM2) and in a Wet Meadow where the last management was at least five years ago (WM4), and in b. recently burned Wet Meadow (WM1) and in a Wet Meadow where the last management was at least five years ago (WM3), in the Tall Grass Prairie Preserve in Manitoba. WM2 and WM4 form a distinct cluster in the NMDS model (see Figures 2 and 3). Pooled species richness for WM1 and WM3 is nine terrestrial and four aquatic gastropod species, and for WM2 and WM4 is six terrestrial and six aquatic gastropod species. See Table 2 for full species names.

and grazing, as well as trampling by cattle, may reduce the mounds of grass litter and impact the aquatic micro-habitat. For this reason, only undisturbed Prairie sites are unique, harbouring a gastropod community composed of both aquatic and dry habitat species. However, our characterization of sites as "undisturbed" or "unmanaged" only means that they have not be subject to grazing or burning in recent years. All sites sampled had a prior history of burning and grazing, with the rotation of these land management practices over time and space nonetheless responsible for this unique faunal assemblage. Without fire at some point, these sites would all have transitioned to Forest or Wet Forest, and thus harbour a different gastropod community. Short term declines in gastropod diversity or abundance that result from management measures may be an essential part of ensuring the long term maintenance of both grassland and the gastropod species dependent on open habitats.

Nekola (2002) indicates that frequent prescribed burns represent a significant threat to the diversity of grassland snail communities, directly and indirectly affecting snail survival. Snails in the upper litter layer die from exposure to high heat during burning (Nekola 2002). Post-burn mortality of snails is also high due to desiccation, due to the loss of shelter and micro-habitats (Ray and Bergey 2015). Fire destroys that part of the soil habitat upon which most litter-soil organisms depend and is therefore the most important factor affecting survival (Bellido 1987). In prairie habitat this means the loss of mounds of grass litter forming moist cavities. At the recently burned Prairie sites soil was bare between the re-establishing mounds of grass litter, but moist cavities were absent. Therefore, aquatic species were negatively affected by the loss of micro-habitat. Burning may be beneficial for forest/grassland species, such as *V. milium* (only observed in the burned Prairie site in our study), which can exploit open-burned habitat close to the forest edge. Similarly, in the

Mediterranean region Santos *et al.* (2012) only found gastropods of the family Geomitridae: Montserrat Heath Snail (*Xerocrassa montserratensis* (Hidalgo, 1870)) and Striped Heath Snail (*Xerocrassa penchinati* (Bourguignat, 1868)), two endemic open-habitat species, in burned sites. The availability of cryptic refuges within these Mediterranean forest patches (Kiss and Magnin 2003, 2006) presumably facilitates the survival of open-habitat snail populations (Santos *et al.* 2012). Likewise, in the tall grass prairie system, the manner in which fire spreads through burn units varies depending on habitat and weather conditions. Skips, or 'refugia', within the burn extent are common (Sveinson Pelc 2013). The resulting patchy consumption of litter layer and exposure of mineral soil allows recolonization from unburned areas. The result is that most sites recently burned (<2 years) had gastropod composition similar to unmanaged sites, demonstrating rapid recolonization in this patchy ecosystem. Ray and Bergey (2015) showed that in favourable weather conditions snail communities in post-burn habitats that include leaf litter showed growth rate increases due to higher soil pH following fire. In Prairie habitat once reestablishment of the litter layer is underway, recolonization from adjacent sites such as Wet Forest patches or drainage sites (especially by aquatic species) can be rapid.

Grazing also contributes to the preservation of the prairie ecosystem mosaic by limiting the spread of woody species and the expansion of forest. In the Tall Grass Prairie Preserve grazing had a significant effect on snail community composition only at Prairie sites where vegetation structure was destroyed. At other sites, grazing intensity (frequency, number of animals, length of grazing period, and their combinations) may be low enough to keep disturbance below a threshold and to maintain snail species composition. When formerly managed grassland was abandoned in Romania, open-habitat gastropod species decreased (Cremene *et al.* 2005). However, grazing intensity negatively influenced the snail fauna in Swiss grasslands, independent of livestock species (Boschi and Baur 2007). Different mechanisms involved in grazing may affect the snail community. The choice of food plants by livestock may impact seed dispersal and therefore plant composition, affecting food sources and micro-habitat for snails. Also, trampling may affect snail survival directly, or indirectly by destroying micro-habitat (Fischer *et al.* 1996; Rook *et al.* 2004). In the Tall Grass Prairie Preserve the structure of mounds of grass litter in Wet Meadow is less important than in Prairie sites. Aquatic species might take more advantage of long periods of flooding in the former. Also, drainages are usually wet and provide a species pool for colonizing wet meadows after periods of drought. Dry-habitat species were absent from the Wet Meadow, however some terrestrial gastropods, such as Fat Hive (*Euconulus polygyratus* (Pilsbry, 1899)) and Amber Glass (*Nesovitrea electrina* (Gould, 1841)) are adapted to both moist and dry habitats and, were present, in Wet Meadow. Two Wet Meadow sites were distinct from all others due to a high abundance of aquatic species which may be the result of a particular flooding regime.

Management recommendations for grasslands in general include low intensity burns that preserve the organic litter layer. Intervals between burns of >5 years (Kiss and Magnin 2006) and >15 years (Nekola 2002) have been recommended to allow for restoration of the gastropod community. However, it is not clear if an interval >15 years would apply in the MTGPP system, where fire rotation historically has ranged 3–6 years (Hamel *et al.* 2006) and is currently 5–6 years. Unfortunately, the gastropod community composition prior to this management strategy is unknown. First Nation fire management was also frequent (<5 years; Lewis 1985). Our observations suggest that short burn intervals have low impact when habitat is patchy, and gastropods can easily recolonize from adjacent unburned areas. In European grasslands, Boschi and Baur (2007) advise extensive grazing. Independent of livestock species, the number of livestock present and the duration of grazing has an impact on the gastropod community. Because there can be an interaction between different management methods (Damhoureyeh and Hartnett 1997), it is difficult to predict the effect of the highly diverse fire-grazing management combinations on gastropod communities in the different habitats of the tall grass prairie system.

Mounds and leaf litter seem to be important for populations of gastropods to recover after burns. Leaf litter supplementation may be a management option.

The gastropod fauna of Manitoba is poorly known and there is little information on the terrestrial molluscs of the Canadian prairie ecosystem. This study increases our knowledge concerning the range of *V. parvula*, *P. minutissimum*, Fine-ribbed Striate (*Striatura milium* (Morse, 1859)), *E.* cf. *praticola*, and Suboval Ambersnail (*Mediappendix* cf. *vermeta* (Say, 1829)), all recorded for the first time in Manitoba during our study. *Vertigo milium*, reported previously in Canada only from a few sites in Ontario and one site in Manitoba (Nekola and Coles 2010) is ranked as Nationally Imperilled to Vulnerable (N2N3, CESCC 2016). *Galba* Schrank, 1803 sp. could not be identified to species because of taxonomic issues, and uncommon grassland species/subspecies within the genus, recorded previously in Alberta (Boag and Wishart 1982) are poorly known.

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Batch spawning in five species of minnows (Cyprinidae) from Ontario, Canada

Norman W.S. Quinn

47 Old Troy Road, R.R. #3, Tweed, Ontario K0K 3J0 Canada; email: normq4@gmail.com

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Abstract

Batch spawning, the act of spawning more than once within a spawning season, is assessed in six species of minnows (Cyprinidae) from Ontario, Canada. The bimodal frequency distribution of egg size in mature specimens suggests that the following species are batch spawners: Blacknose Dace (*Rhinichthys atratulus*), Brassy Minnow (*Hybognathus hankinsoni*), Common Shiner (*Luxilus cornutus*), Creek Chub (*Semotilus atromaculatus*), and Hornyhead Chub (*Nocomis biguttatus*). However, there is no evidence that Northern Pearl Dace (*Margariscus nachtriebi*) is a batch spawner. Thus, we now have evidence that 11 of 39 cyprinid species in Ontario are batch spawners. Knowledge about the reproductive habits of these species should be integrated into the comprehensive standards for the protection of fish habitat in Ontario to ensure the survival of populations.

Key words: Cyprinidae; minnows; spawning; batch; Ontario

Introduction

Batch (or fractional) spawning is widespread among fishes (e.g., Conover 1985). The phenomenon is defined as spawning more than once during a spawning season as opposed to spawning only once in a relatively short period, hereafter, referred to as "conventional" spawning (Conover 1985). Batch spawning presents a problem to fisheries managers because it confounds or renders impossible any attempt to estimate total fecundity (e.g., Conover 1985). Batch spawning has been frequently reported in the minnows (Cyprinidae; e.g., Heins and Rabito 1986).

The objective of this study was to report on the occurrence of batch spawning in some Ontario cyprinids through the examination of ovaries of mature individuals of six species: Blacknose Dace (*Rhinichthys atratulus*), Brassy Minnow (*Hybognathus hankinsoni*), Common Shiner (*Luxilus cornutus*), Creek Chub (*Semotilus atromaculatus*), Hornyhead Chub (*Nocomis biguttatus*), and Northern Pearl Dace (*Margariscus nachtriebi*).

Methods

In 2013–2015, minnows were captured with standard (40 × 20 cm) cylindrical wire traps set overnight from late April (ice out) to 30 June, a period when spawning of these fish is underway. Five of the six species were caught in Clarke Creek (45°06′N, 77° 48′W) near Bancroft, Ontario. Hornyhead Chub was caught in an unnamed creek near Madoc, Ontario (44° 30′N, 77°39′W).

Standard length and weight of fish were recorded on capture. Ovaries were removed and preserved in 10% buffered formalin. The gonadosomatic index (GSI) was calculated as ovary weight divided by total weight (including ovaries). Cyprinids typically spawn with a GSI of about 10% (e.g., Abiden 1986).

The approach used to determine mode of spawning was based on frequency distribution of the size of eggs in ovaries. Batch spawners in or near spawning condition should show a multimodal distribution of egg sizes. Large, fully mature eggs should be observed in the presence of mid-sized eggs, the latter representing the batch to be spawned at a later date. Conventional, one-batch spawners should show only mature eggs amid a mass of very small "recruitment" eggs (Conover 1985; Powles *et al.* 1992) to be spawned the following year. This approach has been used previously, including with cyprinids (Heins and Rabito 1986; Powles *et al.* 1992; Heins and Baker 1993; Wang *et al.* 2014); as Heins and Baker (1993: 15) state, two separate groups of developing eggs is "a profile typical of fish that produce multiple clutches".

Ovaries from specimens in or near spawning condition, that is, having mature eggs (as described below) were examined to determine the frequency distribution of egg sizes. The fixed ovaries were

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weighed to the nearest 0.01 g. A sample of the ovarian matrix was obtained by cutting out two small pieces, one from each ovary. Herrera and Fernandez-Delgardo (1994) and Al Saleh *et al.* (2012) found that the size of eggs is more or less independent of position in the ovaries of minnows. The samples were weighed (typically 0.05–0.15 g) and placed on a glass slide, covered with a drop of water, and the eggs were spread out with the flat of a scalpel. The sample was then examined under a microscope at 40× magnification and all eggs were counted and sorted into one of three size classes: 0.20–0.60 mm, 0.61–1.00 mm, and >1.00 mm. The slides had an underlying grid to help prevent double counting of eggs, and an ocular micrometer was used to measure eggs when size class was not obvious. The overall colour of eggs in each size class was noted.

The size classes correspond to the three categories in Powles *et al.* (1992) for the minnow Northern Redbelly Dace (*Chrosomus eos*): 1) "immature" ("recruitment" in Conover 1985), white-grey with no yolk; 2) "maturing" (or mid-sized), vitellogenic (accruing yolk) and yellow or orange; and 3) "mature", >1.00 mm and translucent, but with yellow hues. Eggs in the mature category were fully developed (Conover 1985; Powles *et al.* 1992). No mature eggs of any observed species were greater than 1.20 mm; thus, it is assumed that size at development stage of eggs of these species and that of *C. eos* eggs is comparable (Brassy Minnow, an exception, is discussed below). The subsamples typically contained 150–400 eggs. An estimate of total number of eggs and number in the three size categories was made by multiplying the weight of the ovary divided by weight of subsample times eggs counted in the subsample. Mid-sized eggs in the presence of mature eggs were deemed evidence of batch spawning.

To produce more precise frequency distributions for graphic illustration, eggs were counted and measured a second time. The subsample was again placed under the microscope and the diameter of 100 eggs measured with an ocular micrometer. To avoid bias, eggs were measured in the order of appearance in the field of view while the slide traversed the field of view. Distorted and ovoid eggs were quite common, but only round eggs were measured.

Results

Most mature female Creek Chub, Common Shiner, Blacknose Dace, and Hornyhead Chub had hundreds of mid-sized eggs in the presence of mature eggs, supporting the hypothesis that they are batch spawners (Table 1). All Brassy Minnow specimens had relatively small eggs. The 12 Brassy Minnow females (caught between 4 May and 24 June in all three years) had GSI >10% and hundreds of vitellogenic eggs, but none >1.00 mm. However, five females had bimodal frequency distributions of egg size (Figure 1l). Thus, Brassy Minnow appears also to be a batch spawner. Northern Pearl Dace is the anomaly in this group; the four mature females had essentially all eggs in the mature category (Figure 1o,p) with negligible immature or mid-sized eggs. With this limited evidence, Northern Pearl Dace appears to be a conventional spawner.

Figure 1 shows selected frequency distributions of egg size (from the 100 measured eggs per specimen). The histograms were selected as typical of patterns observed for each species. Note that most (except for Northern Pearl Dace) show mid-sized eggs in the presence of mature (>1.00 mm) eggs.

TABLE 1. Gonadosomatic index (GSI) and egg-size distribution in mature females of six Ontario cyprinids.

	No. mature females	Mean standard length, cm	Mean GSI, % body weight	No. (%) of fish with mid-sized eggs	Egg-size distribution, means* (%)
Creek Chub (*Semotilus atromaculatus*)	29	11.05	9.78	29 (100)	2603/959/107 (100/36.8/4.1)
Common Shiner (*Luxilus cornutus*)	22	8.40	10.56	22 (100)	1587/427/480 (100/26.9/30.3)
Blacknose Dace (*Rhinichthys atratulus*)	28	7.46	12.95	25 (89)	1440/245/535 (100/17.0/37.2)
Brassy Minnow (*Hybognathus hankinsoni*)	12	7.74	10.76	—†	3294/0/1028 (100/0/31.2)
Hornyhead Chub (*Nocomis biguttatus*)	8	9.52	14.31	8 (100)	2560/723/850 (100/28.2/33.2)
Northern Pearl Dace (*Margariscus nachtriebi*)	4	7.90	15.87	0	775/757/28 (100/97.7/3.6)

*Means of total no. eggs/mature eggs/mid-sized eggs. Mature eggs >1 mm, mid-sized 0.6–1.0 mm.
†Size categories of eggs of Brassy Minnow are an exception (see text for explanation).

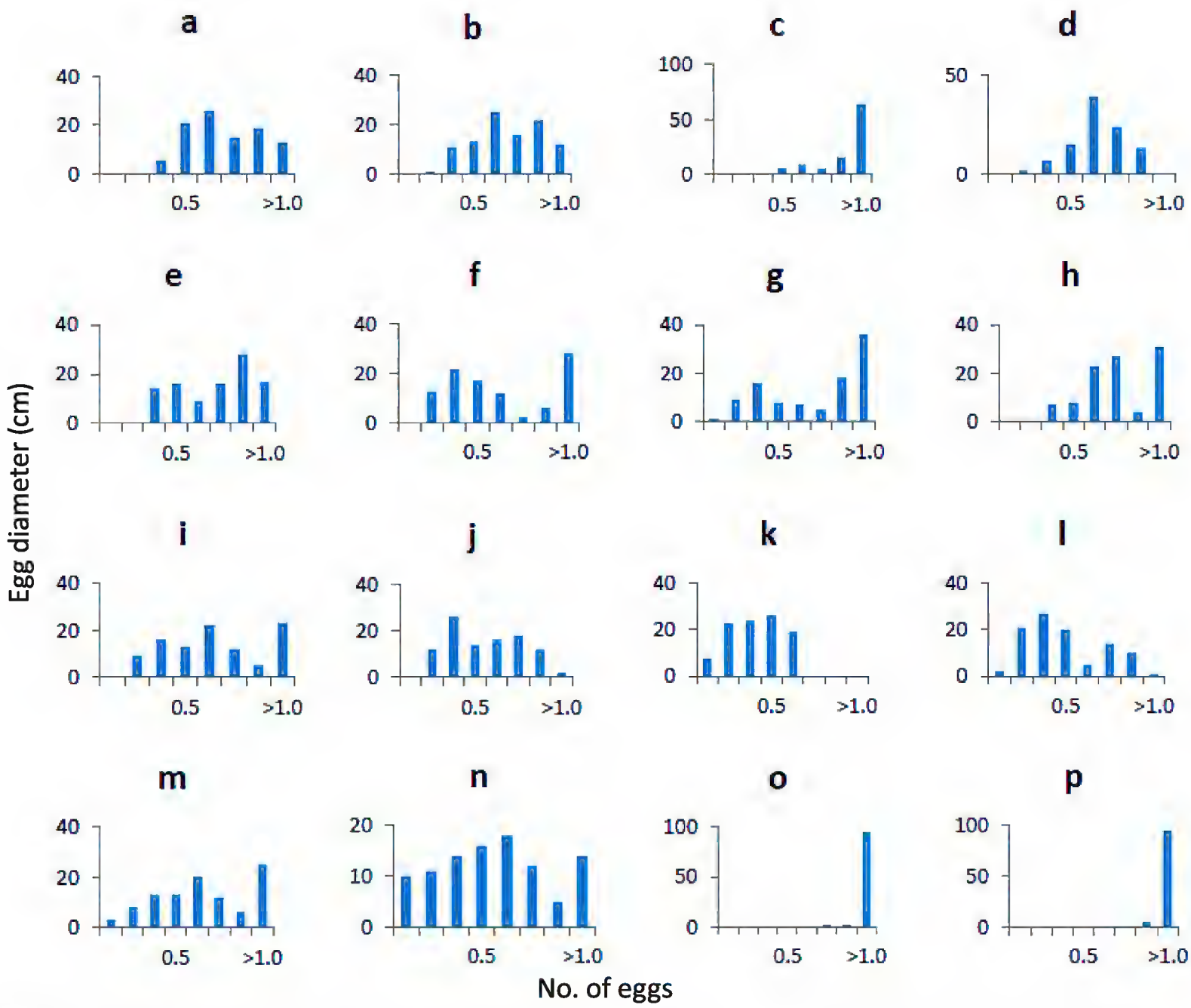

FIGURE 1. Selected egg-size distributions for six Ontario cyprinids. a–d: Creek Chub (*Semotilus atromaculatus*), e–g: Common Shiner (*Luxilus cornutus*), h–j: Blacknose Dace (*Rhinichthys atratulus*), k and l: Brassy Minnow (*Hybognathus hankinsonii*), m and n: Hornyhead Chub (*Nocomis biguttatus*), o and p: Northern Pearl Dace (*Margariscus nachtriebi*).

Discussion

Batch spawning is reported frequently in the Cyprinidae and from locations as disparate as Spain (Herrera and Fernandez-Delgrado 1994), Iraq (Al Saleh *et al.* 2012), and Malaysia (Abiden 1986). Conventional spawning is also occasionally reported (e.g., Wang *et al.* 2014). This study adds five species to the six cyprinid species already documented as batch spawners in Ontario. These other species are: Blacknose Shiner (*Notropis heterolepis*; Roberts *et al.* 2006), Bluntnose Minnow (*Pimephales notatus*; Gale 1983), introduced Common Carp (*Cyprinus carpio*; Ivanov 1976), Fathead Minnow (*Pimephales promelas*; Gale and Buynak 1982), introduced Goldfish (*Carasius auratus*; Ivanov 1971), and Northern Redbelly Dace (Powles *et al.* 1992). Thus, 11 of the 39 Ontario cyprinids have been confirmed to be batch spawners.

This study suggests that Northern Pearl Dace is a conventional spawner. The evidence for batch spawning reported here is indirect because direct observation in the field is difficult (Conover 1985).

Ontario has developed comprehensive standards for the protection of fish habitat (e.g., Anonymous 2006). For example, timing restrictions force work in water away from periods when spawning or egg development may occur (Anonymous 2006). In systems with complex fish communities, this can mean that work is restricted to a few weeks in late summer. However, because of batch spawning, the reproduction of cyprinids may be prolonged; some species, for example, Fathead Minnow, spawn more than 15 times in a season (Gale and Buynak 1982). Such a prolonged spawning period suggests that even late summer restrictions may be inadequate to fully protect cyprinid populations.

The evolution of batch spawning has been interpreted according to three adaptive scenarios or hypotheses. It may be a "bet hedging" life history pattern

(Morrongielo *et al.* 2012), whereby a variable post-hatch environment and consequent unpredictable mortality of young favour a reproductive effort that is spread out temporally, thus increasing the probability of survival of the progeny. Second, Schlosser (1998) and Matthews *et al.* (2001) suggest that fish in confined environments, such as streams, extend reproduction to minimize intraspecific competition for the developing young. Third, Coburn (1986) argues that developmental and ecological factors limit egg size to a certain minimum. Thus, fish with small adult body size, having smaller ovaries, compensate for less output by laying multiple clutches.

More basic research and data on cyprinid reproductive patterns are needed to verify these adaptive hypotheses.

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Note

High reliance on a diet of Moose (*Alces americanus*) by Eastern Coyotes (*Canis latrans* var.) in Cape Breton Highlands National Park, Nova Scotia, Canada

Jason W.B. Power[1,2*], Michael J. Boudreau[2], Erich M. Muntz[3], and Soren Bondrup-Nielsen[1]

[1]Department of Biology, Acadia University, Wolfville, Nova Scotia B4P 2R6 Canada
[2]Current address: Nova Scotia Department of Lands and Forestry, Wildlife Division, 136 Exhibition Street, Kentville, Nova Scotia B4N 4E5 Canada
[3]Cape Breton Highlands National Park of Canada, P.O. Box 158, Cheticamp, Nova Scotia B0E 1H0 Canada
[*]Corresponding author: Jason.WB.Power@novascotia.ca

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Abstract

Eastern Coyote (*Canis latrans* var.) scats were collected along transects in Cape Breton Highlands National Park, Nova Scotia, Canada, from May 2012 to August 2013 to determine diet. Based on 294 scats, Moose (*Alces americanus*) remains made up the highest percentage by volume in scats during fall, winter, and spring. During the summer, Moose remains were found in over 30% of scats (18% by volume), although fruit and berries were more commonly found. No other study has documented such high annual use of Moose. As there was no evidence that the consumed Moose were killed by Coyotes, presumably Coyotes scavenged Moose that had died of natural causes.

Key words: Eastern Coyote; *Canis latrans* var.; diet; Moose; *Alces americanus*; Cape Breton Highlands National Park

Eastern Coyotes (*Canis latrans* var.) were first recorded in Cape Breton Highlands National Park (CBHNP; Figure 1), Nova Scotia, Canada, in 1980 (E.M.M. pers. obs.). A high level of coyote–human aggressive encounters, including a human fatality (E.M.M. pers. obs.), resulted in the park initiating a study of the ecology of Coyotes within its boundaries. One aspect of this study was to understand their diet.

Coyotes typically exhibit a generalist diet (Young and Jackson 1951; Bekoff 1977; Prugh 2005; Lukasik and Alexander 2011) adjusting to seasonal availability of prey and other food sources (Patterson *et al.* 1998; Lukasik and Alexander 2011). Food selection ranges from preying on small mammals, such as rodents and lagomorphs, to large ungulates, livestock, or pets, as well as foraging for fruit, eating garbage, and scavenging (i.e., Bowyer *et al.* 1983; Fedriani *et al.* 2001; Lukasik and Alexander 2011). Eastern Coyotes have been known to prey effectively on adult White-tailed Deer (*Odocoileus virginianus*; Parker 1986; Patterson and Messier 2000) and, more recently, they have been documented killing adult Moose (*Alces americanus*) in Ontario (Benson and Patterson 2013). Here, we report on an unusually high reliance on a diet of Moose by Eastern Coyotes year round in CBHNP.

From May 2012 to August 2013, scats were collected every three weeks from 21 2-km-long transects randomly selected along established paths and trails throughout CBHNP (Figure 1). Percentage by volume for each prey remain was determined using the point-frame method (Chamrad and Box 1964) after scats were washed to retain hair and bones and other hard material and dried. A Kruskal-Wallis test (R Studio, version 0.98.490; R version 3.0.2 reports χ^2) was used to test for differences in prey remains among calendar seasons.

In total, 294 Coyote scats were collected along 966 cumulative km of trail transects. Dietary analysis of these scats indicated that Moose, fruit/berries, and Snowshoe Hare (*Lepus americanus*) made up the highest percentage of volume by season (Table 1).

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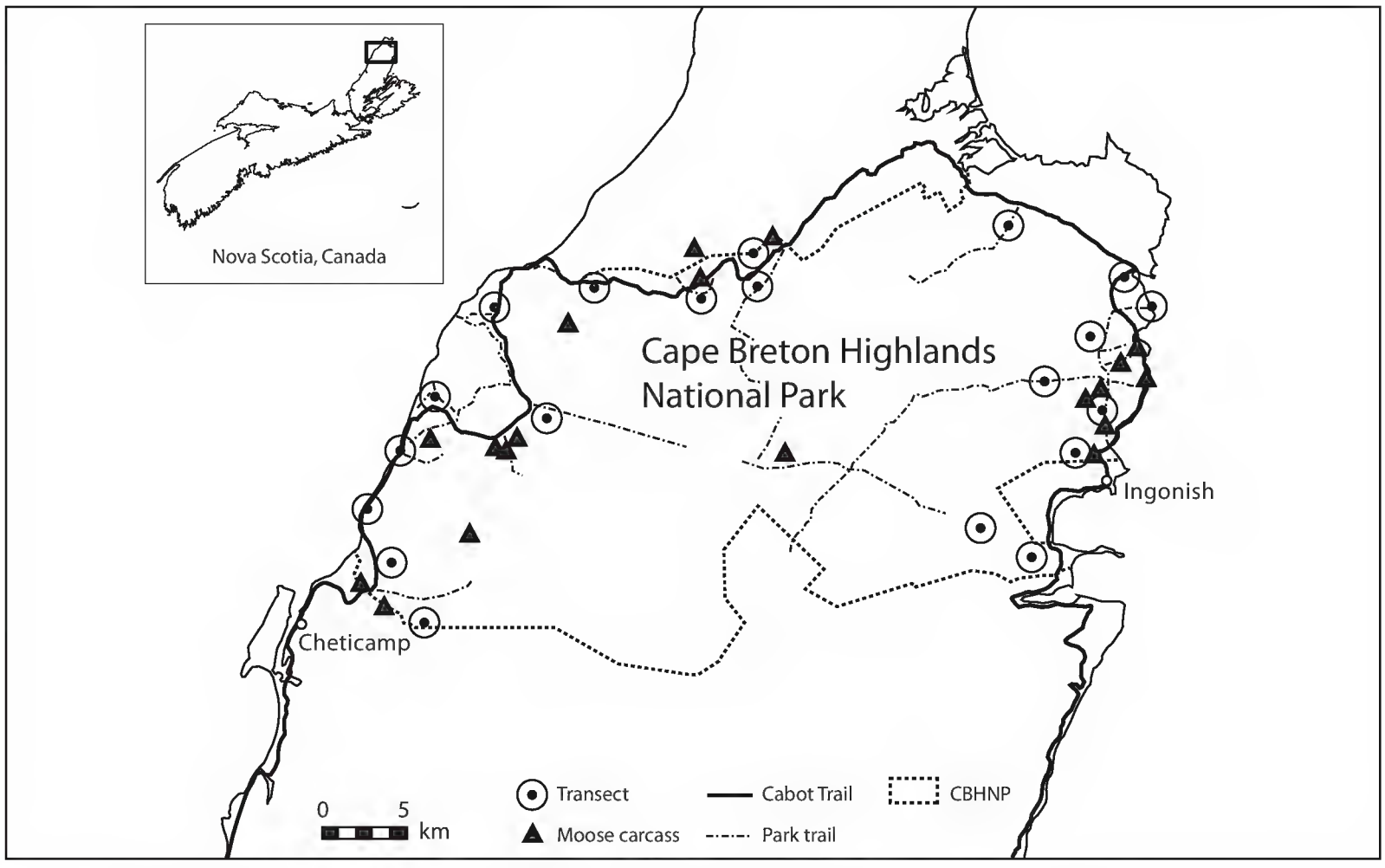

FIGURE 1. Locations of scat transects and Moose (*Alces americanus*) carcasses found between May 2012 and August 2013 in Cape Breton Highlands National Park.

Overall, Moose was the most common food by volume found in Coyote scats (over 70% during spring and winter), followed by fruit/berries (fall 29%, summer 56%) and Snowshoe Hare (winter 25%). Small mammals (23% fall), birds (9% fall), and deer (8% spring) were less common.

While opportunistically back tracking Coyotes (57 tracks for a total of 109 km) in winter, we found 19 Moose carcasses, all female ranging from 1.5 to 10.5 years old (aged by analyzing tooth pattern of lower jaw; Figure 1). None of the carcasses was located on or near scat transects. These carcasses had been scavenged by Coyotes; there was no evidence that Coyotes had killed any of these Moose.

These results indicate that Eastern Coyotes in CBHNP have a generalist diet with a high reliance on Moose. Studies in eastern Maine (Litvaitis and Harrison 1989), northwestern Wyoming (Dowd and Gese 2012), southeastern Quebec (Richer *et al.* 2002), western Maine (Major and Sherburne 1987), and New Brunswick (Dumond *et al.* 2001) have found Moose to make up a smaller proportion of the diet of Coyotes. Only in eastern Quebec did Boisjoly *et al.* (2010) report a high frequency of 51% Moose in scats. Our study documents the highest percentage by volume of Moose in scats of Eastern Coyotes in CBHNP during the winter (71%).

At the time of this study, Moose were likely the

TABLE 1. Analysis of prey remains identified from 294 scats of Eastern Coyote (*Canis latrans* var.) collected on trail transects in Cape Breton Highlands National Park, Nova Scotia, from May 2012 through August 2013.

Dietary remains	% prey by volume (mean ± SD) in each season*				χ^2	*P*
	Fall ($n = 40$)	Winter ($n = 80$)	Spring ($n = 64$)	Summer ($n = 110$)		
Moose (*Alces americanus*)	23.3 ± 39.4	71.2 ± 44.5	70.9 ± 44.5	18.0 ± 35.8	78.98	0.000
White-tailed Deer (*Odocoileus virginianus*)	—	1.2 ± 11.3	7.8 ± 27.0	—	13.99	0.003
Snowshoe Hare (*Lepus americanus*)	16.2 ± 34.6	24.8 ± 42.2	18.1 ± 37.5	11.8 ± 30.4	3.52	0.317
Bird	8.6 ± 24.1	0.9 ± 5.8	1.6 ± 12.5	1.9 ± 6.4	19.76	0.000
Small mammal	22.9 ± 39.6	1.9 ± 12.1	1.6 ± 12.1	12.0 ± 27.6	33.49	0.000
Fruit	29.1 ± 41.9	—	—	56.3 ± 43.1	147.20	0.000

*Fall = 22 September to 20 December, winter = 21 December to 19 March, spring = 20 March to 20 June, summer = 21 June to 21 September.

most biomass-rich food source available to Coyotes, especially in the highlands. Moose density in the highlands of CBHNP is typically high, with well over 1000 individuals in the park (Bridgland *et al.* 2007), although no estimate of Moose density was available during our study period. Gray Wolves (*Canis lupus*) in western Quebec were observed feeding on single Moose carcasses for up to 23 days (Messier and Crête 1985); thus, a Moose carcass could likely sustain a Coyote pack for several weeks as a protein- and energy-rich food source. Furthermore, less energy is likely expended scavenging a Moose carcass during winter and spring months compared with hunting small mammals. Cyclical lows of the Snowshoe Hare population during this study (E.M.M. pers. obs.) may have contributed to the primary occurrence of Moose in Coyote scats. Coyotes in CBHNP may rely on Moose carcasses because of their apparent availability and the lack of other prey, such as Snowshoe Hare, a common food source of Coyotes in other parts of Nova Scotia (Patterson *et al.* 1998).

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A review of the historical and current status of American Beaver (*Castor canadensis*) on Prince Edward Island, Canada

Rosemary Curley[1, 2,*], David L. Keenlyside[3], Helen E. Kristmanson[4], and Randall L. Dibblee[1,5]

[1]Department of Agriculture and Forestry, P.O. Box 2000, Charlottetown, Prince Edward Island C1A 7N8 Canada
[2]Current address: 9 Harland View Drive, Stratford, Prince Edward Island C1B 1W2 Canada
[3]Prince Edward Island Museum and Heritage Foundation, 2 Kent Street, Charlottetown, Prince Edward Island C1A 1M6 Canada
[4]Intergovernmental and Public Affairs, Aboriginal Affairs Secretariat, P.O. Box 2000, Charlottetown, Prince Edward Island C1A 7N8 Canada
[5]Current address: 672 St. Catherine's Road, Bonshaw, Prince Edward Island C0A 1C0 Canada
*Corresponding author: rcurleypei@eastlink.ca

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Abstract

Evidence supporting the native status of American Beaver (*Castor canadensis*) on Prince Edward Island (PEI) before European contact in 1534 has yet to be established; however, the postglacial and archaeological records have not previously been reviewed in this context. We demonstrate the coincidence of a land bridge between the mainland and PEI and the occurrence of beavers in the region dating between 9500 and 5000 BP (before present, with present defined as 1950). We provide an archaeological record of 14 beaver incisors in six locations, deposited between 500 and 1650 AD and also show that beavers could swim to PEI. Based on this evidence, we conclude that beavers were native to the province. The current population, originating via reintroductions from New Brunswick, has populated much of the available habitat and engendered considerable controversy.

Key words: American Beaver; *Castor canadensis*; status; dispersal; Prince Edward Island; history; archaeology

Introduction

The historical status of mammals of Prince Edward Island (PEI) during the early years of European contact and settlement has been extensively researched by Sobey (2007). While admitting that American Beaver (*Castor canadensis*) may have been extirpated from PEI before 1700, he believed that the evidence supporting native status for this species in the province was remarkably weak. In a more recent review of mammal status in the region, the beaver has been described as extirpated from PEI and reintroduced (Forbes *et al.* 2010), but without supporting details. With regard to the existing population, Cameron (1958) noted the reintroduction of beavers to PEI from Algonquin Park, Ontario, in 1908–1910 and Dibblee (1994) found contemporary records of importation by private individuals; however, both efforts were unsuccessful because of unregulated trapping. The current PEI population originated via reintroductions from New Brunswick (NB) after 1940 (Cameron 1958; Dibblee 1994).

It is perhaps the uncertainty about beaver status on PEI that led the Atlantic Salmon Federation to label the beaver a non-native species and to call for its removal from several eastern PEI rivers as part of a conservation strategy for Atlantic Salmon (*Salmo salar*; Guignion 2009). Similarly, Cairns *et al.* (2010) suggested that the beaver's effect on Atlantic Salmon associated with river damming could be classified as (negatively) anthropogenic, rather than natural. However, management decisions about beavers on PEI should be based on a comprehensive understanding of the historical and current status of the species.

When assessing mammal colonization of islands, Mazza *et al.* (2013) suggest considering palaeontological, climate and sea-level evidence, characteristics and behaviour of the species, the historical record, and the primary source of information, the fossil record. To determine whether the beaver is an alien species on PEI or a native mammal that was extirpated and reintroduced, we reassess the historical evidence from Sobey (2007) and others, as well as

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the post-glaciation history and geography of the province, and archaeological materials. Finally, we present the current status of the beaver in the province.

Methods

We reviewed both historical and scientific literature for references to beavers and beaver habitat on PEI and elsewhere. Our search included local history documents, scientific literature, government reports, archaeological reports, and collections at the Canadian Museum of History and Parks Canada (Halifax). Sobey's (2002, 2006a,b, 2007) wildlife history research covered much of the historical account.

Archaeological field research was undertaken by D.L.K. from 1980 to 2008 and by H.E.K from 2009 to 2018. Dating of beaver teeth from these archaeological studies was based on the site characteristics, cultural associations, and, more specifically, radiocarbon dating of associated charcoal in shell middens at South Lake and Greenwich. An incisor from MacMillan's Point was radiocarbon dated through accelerator mass spectrometry at Beta Analytic Testing Laboratory (Miami, Florida, USA). Dr. Frances Stewart, a peer-recognized leading zooarchaeologist for eastern Canada with an extensive reference collection of skeletons, determined the species identity of bones at George Island.

The distance beavers may have swum or rafted to get to islands was calculated using Google Earth (Keyhole, Inc., Mountain View, California, USA). Where island hopping was possible, the longest open-water swim using islands was calculated, as well as the straight-line distance through water.

Monitoring of beaver populations from 1972 to 2007 was conducted by R.L.D. while employed by the PEI government. Areas of beaver-influenced wetlands were delineated and measured on aerial photos from 1990, 2000, and 2010 captured at a 1:17 500 scale (PEICLUI 2010). Beaver dams and the triangular flooded areas behind them are readily recognized at this scale. Wetland sizes ranged from 0.1 to 240 ha.

In 1990 and 2000, coverage of PEI included the use of infrared photography. Both active and inactive beaver dams were delineated on the 1990 photographs. Each photo was overlain with a same-scale transparent map showing roads and streams. These lines were then transferred to the map and digitized to create the first vector-based PEI wetland inventory. In 2000, the analog film was then scanned and the resultant imagery used to create complete orthorectified imagery of PEI. Using the orthomaps and existing digital 1990 inventory, the 2000 PEI wetland inventory, including beaver dams, was incorporated into a province-wide digital land use inventory.

In 2010, digital imagery was acquired in both colour and colour-infrared with 40-cm resolution. Softcopy photogrammetry was used to generate the PEI 2010 Land Use Inventory in which the same interpretation parameters were applied.

Results

Historical evidence of Castor canadensis

Cameron (1958: 45) listed the beaver as a native mammal in PEI, taking as proof "the presence of beaver tooth marks on sticks found in peat bogs", but presented no further details. Sobey (2007) acknowledged no firsthand account of beavers in the PEI historical record since French settlement in 1721. There are two early French reports. In 1721, Denys de La Ronde stated that there were no beavers in Ile Saint-Jean (as it was then named; Sobey 2007). However, footnoted evidence reveals that Père René-Charles Breslay, who lived in Ile Saint-Jean from 1721 to 1723, took eight beaver skins to France (Sobey 2006a). Beavers were included in an 1802 shipment of pelts and an 1808 list of pelt prices from PEI. It is notable that credible mammal listers (e.g., Johnston 1822; MacGregor 1828) in the early 1800s failed to include the beaver for the island. Peter Sinott emigrated to PEI in 1821 and stated in 1876 that the beaver had been present when he was younger (Sobey 2006b), whereas, in the late 19th century, the opinion of a permanent resident, Sutherland (1861), and the visiting Rowan (1876) indicated an absence of beavers (Sobey 2007). A Summerside Journal article by Marks (1900) related the words of an old gentleman that the last beaver he saw had been killed 40 years earlier, ca. 1860, and the 31 October 1916 Charlottetown Guardian reported that the late Professor Caven of Prince of Wales College, Charlottetown, had found traces of beaver dams on the Dunk River (Dibblee 1994). Naturalist Francis Bain (1890) reiterated that remains of beaver dams could still be seen.

Glacial and post-glacial history, geography, and dispersal

The current PEI mammalian fauna arrived after glaciers retreated about 11 000 BP (before present, with present defined as 1950; Shaw *et al.* 2006). Although overland access to PEI was necessary for some species and facilitated by a land connection that was in place from 9500 to 5000 years BP across what is now Northumberland Strait (Kranck 1972; Shaw *et al.* 2002), it is unlikely that the now-flooded strait is a barrier to beaver dispersal (Table 1). On PEI, several specimens of River Otter (*Lontra canadensis*), previously regarded as extirpated, have been collected since 2016 (G. Gregory pers. comm. 20 June 2019) including a juvenile that was whelped on PEI, although at least some have swum or travelled on ice across 13+ km of marine waters, identical to distan-

TABLE 1. Unassisted occupation of islands by American Beaver (*Castor canadensis*) and the shortest straight-line distances by water, measured using Google Earth.

Island and jurisdiction	Water body	Distance to mainland or island (km)	Salinity	Reference
Nueva Island, Chile	South of Beagle Channel	6.5–11.5*	Marine	Anderson *et al.* 2009
Lennox Island, Chile	South of Beagle Channel	6	Marine	Anderson *et al.* 2009
Admiralty Island, Alaska	Stephens Channel	3.5	Marine	MacDonald and Cook 1996
Isle Royale, Michigan	Lake Superior	23	Fresh	Mech 1966
Grand Manan Island, NB	Bay of Fundy	11	Marine	Ingersoll and Gorham 1978
Newfoundland, NL	Strait of Belle Isle or other route	17+	Marine	Cameron 1958
Cape Breton Island, NS	Strait of Canso	1	Marine	Cameron 1958
Prince Edward Island	Northumberland Strait	13	Marine	Cameron 1958; this study
George Island, PEI	Malpeque Bay	1	Marine	This study

Note: NL = Newfoundland and Labrador, NB = New Brunswick, NS = Nova Scotia, PEI = Prince Edward Island.
*With possible island hopping, the longest open-water swim using islands is shown as well as the shortest possible distance by water.

ces regularly swum by River Otters in marine waters of Alaska (Blundell *et al.* 2002). The beaver and the otter were regarded as equally effective dispersers in colonizing insular Newfoundland and Labrador (Dodds 1983), and possibly not via the narrow but turbulent Strait of Belle Isle (Cameron 1958).

Beavers from Minnesota, USA, have dispersed to Isle Royale, Michigan, USA, at least twice across 23 km of freshwater in recent times (Mech 1966), far exceeding the 13 km that a beaver would need to swim to PEI. American Beavers commonly occupy inshore islands in Canada (Naughton 2012), and a rejuvenated beaver population in Newfoundland arrived at several smaller offshore islands in the mid-1900s (Dodds 1983). R.C. has twice seen a beaver swimming along the shore in coastal areas of PEI, as well as a beaver dam constructed across a coastal salt marsh. Beavers are well adapted to an aquatic environment, and they have several features that also protect them in marine waters. They breathe only through the nose and can prevent accidental swallowing of water. When they are underwater, flaps close off their nose and ears and a membrane protects the eyes (Naughton 2012). They are also buoyant and predisposed to enter the water, characteristics that enable colonization of islands (Mazza *et al.* 2013).

On Cape Breton Island, Nova Scotia (NS), beaver presence was recorded by 9500 years BP (Gorham *et al.* 2007); thus, they were present in the Maritimes during the 4000-year period when the extensive land connection between PEI and NB and NS was in place (Kranck 1972; Shaw *et al.* 2002).

Archaeological record of beavers on Prince Edward Island

Sobey (2007) acknowledged the beaver incisor excavated at South Lake by Keenlyside (1982, 1983) but did not look for other records. The archaeological record for the Maritimes has been evaluated (Murphy and Black 1996). Because of the great influence of coastal erosion and relative rise in sea level, many possible sites of older coastal encampments of Indigenous peoples have long since disappeared under water. As well, pre-contact shell middens were systematically spread on the land by PEI farmers to counteract soil acidity and, thus, their contents were plundered and/or dispersed (Gesner 1846).

There are 14 archaeological collections of beaver material from six sites, all with deposition dates after the postglacial flooding of Northumberland Strait (Table 2). Incisors are the most easily identified beaver remains and, thus, are often noted immediately when found, as at the Sutherland site, Greenwich (CcCp-7; Keenlyside 2002).

Faunal remains of beaver are currently known from four prominent archaeological sites on PEI (Figure 1). The MacDonald site (CcCm-12), located in South Lake, Kings County (Keenlyside 1982, 1983), consisted of two cultural components: a probable Acadian early-mid 18th century historical occupation, and a second underlying late Maritime Woodland occupation dating to about 600–900 AD. Associated with the earlier indigenous occupation was a cut beaver incisor section that appears to have been used as a bit for a cutting or incising implement. No post-cranial elements were identified in the site faunal sample.

The finds from the Sutherland site at Greenwich (CcCp-7) located on the north shore of St. Peters Bay, Kings County, now part of Prince Edward Island National Park (PEINP; Keenlyside 2002), included a modified incisor recovered from a test pit in a shell midden deposit, one of several found. The site revealed extensive habitation covering 2–3 ha and dates from 800 to 900 AD, a similar period as at the MacDonald site.

The split incisors found at Rustico (Robinson) Island in PEINP were used as a knife by Indigenous

TABLE 2. Known remains of American Beaver (*Castor canadensis*) incisors deposited 500–1650 AD and obtained from archaeological excavations and opportunistic collecting on Prince Edward Island during 1980–2017.

Sample	Location collected	Collection date	Collector*	Approximate years deposited, AD ± SD (range)	Normalized age,† years BP/1950 ± SD	Voucher	Reference documents	Comments
Piece of incisor	MacDonald site, South Lake (CcCm-12)	Several seasons 1980s	DLK	900 ± 100 (800–1000)	1480 ±160	CMC CcCm-12: 506	Keenlyside 1982, 1983; Morlan n.d.	From shell midden
Piece of incisor	MacDonald site, South Lake (CcCm-12)	1980	DLK	900 ± 100 (800–1000)	1480 ±160	CMC CcCm-12: 343	Keenlyside 1982	23–28 cm deep
Incisor	Sutherland site, Greenwich, PEI National Park (CcCp-7)	1994–1995	DLK	750 ± 250 (500–1000)	1200 ± 250	CMC CcCp-7: 1481	Keenlyside 2002	In bank
Two incisor fragments	Sutherland site, Greenwich, PEI National Park (CcCp-7)	1985	DLK	1100 ± 300 (800–1400)	1280 ±100	CMC CcCp-7: 481, 482	Keenlyside 2002; Morlan n.d.	Eroding bank with shell midden; dated by ceramic inclusions; 1.8 cm cut; 1.9 cm fractured and cut (one side only)
Lower incisor	Sutherland site, Greenwich, PEI National Park (CcCp-7)	2000–2001	DLK	1100 ± 300 (800–1400)	1280 ± 100	CMC CcCp-7: 1928	Keenlyside 2002; Morlan n.d.; Stewart 2002	Split, end cut and smoothed; in plough zone
Enamel fragment of incisor and fragment of incisor	Sutherland site, Greenwich, PEI National Park (CcCp-7)	2000–2001	DLK	1100 ± 300 (800–1400)	1280 ± 100	CMC CcCp-7: 2209, 2245	Keenlyside 2002; Morlan n.d.; Stewart 2002	34–43 cm deep
One upper and one lower incisor	Robinsons Island, PEI National Park (CcCt-1)	1987–1988	BWF	1480 ± 50 (1430–1530)	470 ± 50	7F2J1-800: 7F11D5-801‡	Leonard 1989; Wallace Ferguson 1989	Split, ground, and polished for use as a knife
Lower incisor	MacMillan's Point, Covehead Bay	1991	WJ	1560 ± 90 (1470–1650)	320 ± 30	Private collection	Kristmanson pers. comm.	Calcined tooth in a fire pit, plowed field; buried about 30 cm in soil

TABLE 2. *Continued.*

Sample	Location collected	Collection date	Collector*	Approximate years deposited, AD ± SD (range)	Normalized age,† years BP/1950 ± SD	Voucher	Reference documents	Comments
Lower incisor	George Island, Malpeque Bay (CdDw-5)	2006	HEK	Undated (N/A)	Unknown	To be deposited PEIMHF	Kristmanson 2007, 2009	In woodland opening; no evidence of modification or use-wear
Incisor fragment	George Island, Malpeque Bay (CdDw-5)	2017	HEK	Undated (N/A)	Unknown	To be deposited PEIMHF	Kristmanson 2018	From *in situ* deposits, pre-contact to historic shell midden site, Pitawelkek
Upper incisor	Darnley Basin, Malpeque (CdCw-9)	2017	HEK	Undated (N/A)	N/A	To be deposited PEIMHF	Kristmanson unpubl. data	Surface collected from pre-contact to 18th century site

Note: CMC = Canadian Museum of History, PEIMHF = Prince Edward Island Museum and Heritage Foundation (2 Kent Street, Charlottetown, Prince Edward Island C1A 1M6), SD = standard deviation.
*Collectors: BWF = Birgitta Wallace Ferguson, DLK = David Keenlyside, HEK = Helen Kristmanson, WJ = Wayne Jordan.
†Age of the site based on radiocarbon dating.
‡Parks Canada Collections and Conservation Facility, 50 Neptune Crescent, Dartmouth, Nova Scotia.

people (Leonard 1989; Wallace Ferguson 1989), but not all teeth were modified. For instance, the complete incisor at a George Island (Pitawelkek) site, where exploration continues, showed no modifications of any kind (Kristmanson 2007, 2009), nor did the MacMillan Point specimen. The latter had been found in an old fire pit in a plowed field about 6 km from the Rustico Island site (H.E.K. unpubl. data).

A rib fragment from an immature beaver, an undated phalanx, and incisor fragments were recovered from excavations at the Pitawelkek site on George Island. These are in general association with radiocarbon dates of ca. 700–800 AD through to the recent historical period. For now, the age of the occupation has been cautiously extended back to at least 0 AD based on the collection of diagnostic artifacts at the Pitawelkek site and other locations on George Island (Kristmanson 2019). The Malpeque site is a cultivated field where it is believed that shell middens were spread on the land (Gesner 1846).

Current status of beaver

The history of beaver reintroductions was investigated by Dibblee (1994). Following the earliest importations from Ontario in 1908 and from an unconfirmed source in 1912, the population rose to an estimated 500 beavers over several river systems. However, high fur prices in the 1920s and unregulated trapping resulted in the animals' disappearance. No beaver dams were detected on 1935 aerial photos. In the late 1940s, a migratory birds protection officer, Spurgeon Jenkins, obtained beavers from NB biologist Bruce Wright, and introduced them into PEI. Thus, Dibblee concluded that all beavers now present in PEI originated from NB.

Beavers were initially introduced east of Charlottetown, but by 1973 the population had expanded. Between 1973 and 1979, government personnel removed 32 beavers from eastern PEI where they were considered to be a nuisance and released them into watercourses of Prince County, where no beavers were present. In January 1981, the first short open season for trapping beavers took place in Prince County, when 20 beaver "problems", such as blocked culverts and flooded driveways indicated an expanded population (Dibblee and Curley 1980). By 2000, the island was well populated with beavers, although few were recorded in the hilly central portion of the island with its flashy streams (a flashy stream is one that rapidly collects flows from the steep slopes of its watershed basin and produces flood peaks soon after the rain but the flow quickly subsides after the rainfall ends). This habitat is less suitable for beavers (Novak 1987), and most are situated to the east and west on rivers with low gradients (Figure 1).

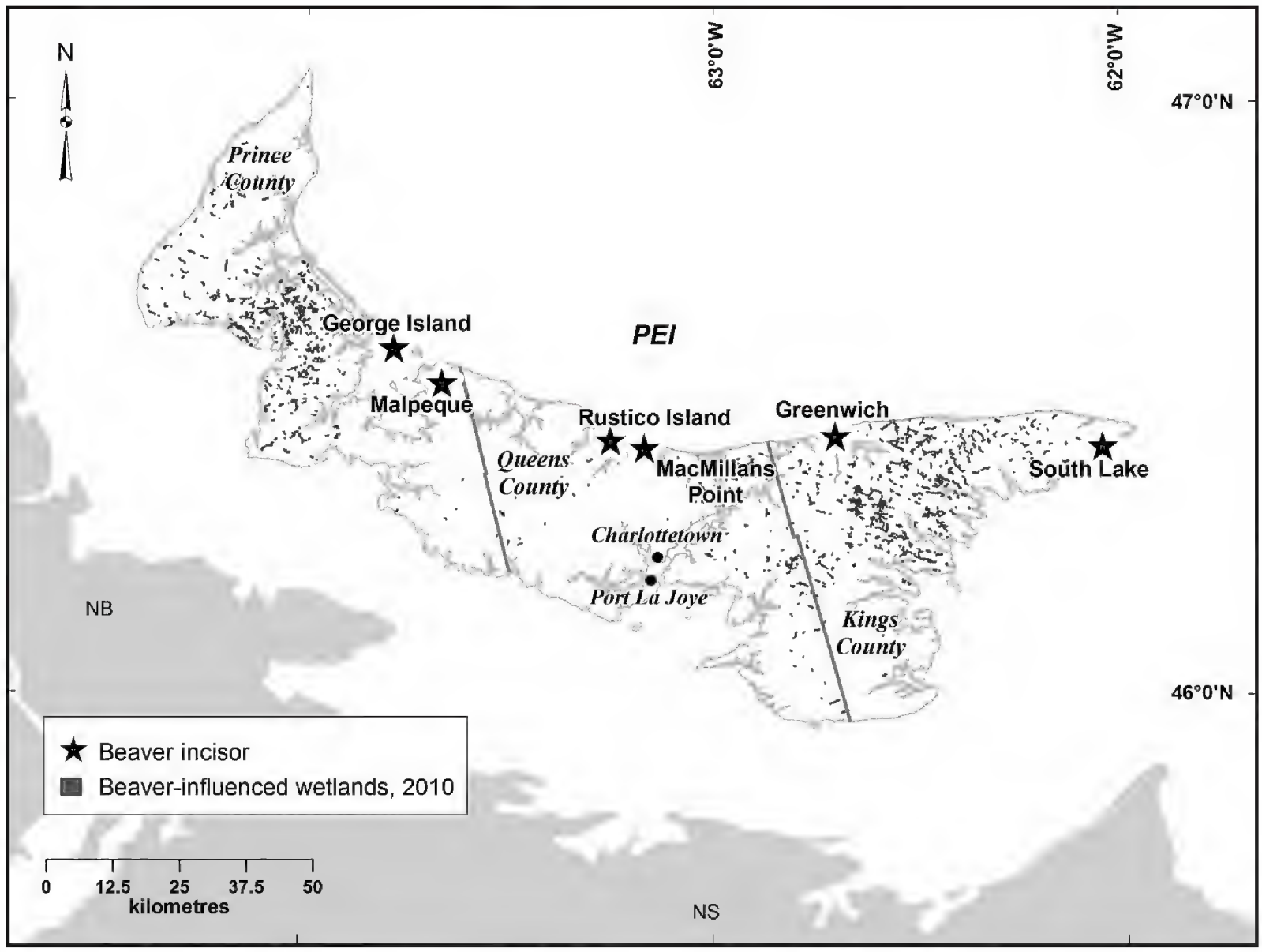

FIGURE 1. Locations of intact or partial American Beaver (*Castor canadensis*) incisors and other geographic points of interest, Prince Edward Island, Canada, plus active and inactive beaver-influenced wetlands delineated in the Prince Edward Island Corporate Land Use Inventory (PEICLUI 2010).

According to data maintained by the provincial fish and wildlife agency, from 1975 to 2015, an average of 465 beavers (one per 11 km^2) were trapped each year, varying from 91 in 1975 to 917 in 2011. Between 1972 and 2002, aerial surveys of index watersheds totalling 1363 km^2 of predominantly forested habitats were conducted by the province. Results indicate a peak of 276 active colonies in 1993 and 160 in 2002. The total wetland area of both active and inactive beaver flowages in PEI was calculated from aerial photography as 2233 ha in 1990, 3395 ha in 2000, and 5304 ha in 2010.

Beavers dams are often perceived as detrimental to salmonid populations (Kemp *et al.* 2012), and watershed enhancement groups express concerns regarding Brook Trout (*Salvelinus fontinalis*) and Atlantic Salmon migration. Beaver numbers fluctuate inversely with fur prices and are a continuing issue for wildlife managers dealing with complaints. Many of the 24 community-based watershed groups have considered beavers in their long-term management plans, as encouraged by the PEI Beaver Management Policy (Anonymous 2011). In practice, plans often direct removal of beavers from the main stem of a river. A local watershed group continues to remove all beavers from northeastern rivers on PEI to support spawning of a unique population of Atlantic Salmon (Moore *et al.* 2014).

Discussion

Previous records of beavers

In evaluating the historical evidence of PEI mammals, Sobey (2007) gave credence to first-hand accounts or records as verifying or disputing the presence of various species. The acceptance of claims that beavers were not present in the province led him to explain away a considerable body of evidence that beavers may have been present. Two (Sutherland 1861 and Rowan 1876) of three mammal recorders who stated that beavers were not present produced their reports in the last half of the 19th century when the few beaver records may have been of new arrivals from the mainland after a long period of absence. Rowan (1876), a travel writer who merely visited the province, also later stated in the same publication that beavers were extirpated from PEI.

These writings likely do not meet the standard of a first-hand account, nor, we assert, would the observations by Denys de La Ronde, a naval officer, who spent only 13 months in PEI beginning in 1721, including time to travel to Louisbourg, Cape Breton Island (Sobey 2002). Although Denys de La Ronde visited all active PEI harbours, the French population in 1721 was perhaps 200 (Harvey 1926). Local knowledge of wildlife would be cursory and cleared land scarce. Denys de La Ronde could not have spoken from personal knowledge of PEI beaver habitats, which would consist mainly of forested river systems extending to the coast in a land mass exceeding 5000 km^2. He may have obtained information from Mi'kmaq traders at Port la Joye, the seat of French government in Ile Saint-Jean, or from fishermen, but he did not acknowledge the source of his information. Harvey (1926) also calls into question his veracity as a reliable reporter.

Novak (1987) reasoned, based on food availability, that beavers likely existed at lower densities in mature forests of the 1500s and the 1600s compared with the high beaver populations in the food-rich early successional riparian forests of today. Beavers prefer young saplings as food and only cut large trees further away from water when saplings are depleted (Gallant *et al.* 2004). PEI has short river systems and human travel in the pre-settlement mature forests dominated by American Beech (*Fagus grandifolia* Ehrhart) was relatively easy, with some exceptions (Sobey 2002). Thus, we speculate that beavers, present according to the archaeological record, were relatively accessible. They live in families of two adults and potentially three or four kits and two or three yearlings (mean group size in central Ontario is 7.5; Novak 1987), and their lodges are easily identified and exploited.

Fur trading began in the Maritimes in the mid-1500s when Basque and French vessels began fishing for cod in the Gulf of St. Lawrence and exchanging goods with the Mi'kmaq (Ray 1987; Cook 1993; Whitehead 1993). Nicolas Denys had an exclusive license to enter into trade for fur and fish in the gulf dating from 1654, and PEI was included in his grant. A cod fisherman and now respected author, Denys (1672) recorded the presence of Basque ships in PEI waters and discussed how beaver pelts were obtained. The Mi'kmaq scared beavers from their lodges in winter, clubbed or harpooned them, taking all within the colony, and also took beavers during ice-free seasons by draining their dams and attacking them with spears and arrows. They met a strong economic demand for beaver pelts from Europeans, and extirpation in PEI in the 1600s or earlier is a possibility, as noted by Sobey (2007). A reinterpretation of Sobey's information discarding Denys de La Ronde's opinion might also indicate that the beaver persisted into the 1800s. The decades of greatest beaver harvest in North America as a whole were 1700–1709 and 1790–1799 (Novak 1987; Obbard *et al.* 1987).

Archaeological record, glacial, and post-glacial history

Sobey's research (2007) does not take into account the archaeological record for PEI. In 1995, archaeological research on PEI constituted only 2% of published and unpublished primary studies in the region (Murphy and Black 1996). Studies are needed from inland freshwater sites where beavers might naturally be found.

Additional factors may also explain the lack of bones. According to religious custom assuring continuation of the beaver, bones from beavers that were consumed by Mi'kmaq were not thrown into the fire or river, nor fed to dogs, although practices vary in detail and by location (Denys 1672; Wallis and Wallis 1955; Robinson and Heller 2017). Bone material and metal goods are generally not preserved in the acidic soils of PEI except in acid-neutralizing shell middens (Murphy and Black 1996). Indigenous peoples consumed beavers, and because beaver incisors were often used as cutting tools, their remains are found in the common areas of preservation, kitchen middens.

Of the 14 records of beaver teeth presented here, not all have been dated, but dated specimens were deposited from about 500 AD to as late as 1650 AD. The teeth could have been imported to PEI as tools (Sobey 2007; M. Betts pers. comm. 12 June 2013) but we have also shown that beavers swim or raft to islands, sometimes far offshore. The simplest explanation for the presence of beaver teeth at PEI archaeological sites is that they are the remains of PEI beavers. As well, the rib bone of an immature beaver at a site that may be 2000 years old, suggests that beavers were breeding on PEI. Discounting this, one must find an explanation as to why beavers did not swim or raft to PEI, as they did to Newfoundland, or disperse to PEI when a land bridge was in place for 4000 years.

With postglacial warming temperatures, vegetation on the island changed rapidly from tundra (suitable for beavers; Aleksiuk 1970; Jung *et al.* 2016; Tape *et al.* 2018) to forest, a spruce (*Picea* sp.)–nonarboreal birch (*Betula* sp.) association between 10 000 and 8000 years BP, followed by pines (*Pinus* sp.; Anderson 1980). The presence of beaver on Cape Breton Island 9500 years BP (Gorham *et al.* 2007) aligns well with the maximum connection of the PEI land mass to the mainland 9000 years BP, a continuous land mass lasting until 5000 years BP (Shaw *et al.* 2002). Beavers are also efficient dispersers (Leege 1968; Hodgdon 1978; Sun *et al.* 2000) and can swim

long distances. We cannot identify any impediments to beavers populating the non-island in early post-glacial times or any dramatic ecosystem changes that would preclude beavers colonizing PEI. A land bridge and the presence of beavers in the region might suggest that they inhabited PEI soon after deglaciation. The ability of beavers to swim or raft to islands is convincing evidence that they inhabited PEI prior to 1534. Archaeological evidence indicates the presence of beavers until at least 1650 AD.

Current status of beaver

The second-growth riparian forests of PEI provide suitable beaver habitat and the beaver has populated most of it. It is likely that human conflicts with beavers and their dams will persist as long as beavers flood transportation corridors and are viewed as negatively influencing the spawning success of salmonids.

Conclusion

It is quite credible that the beaver could have been extirpated from PEI in the roughly 200 years before French settlement in 1721. Extinction rates of mammals are orders of magnitude higher on islands than elsewhere and are often related to human predation in historical times (Loehle and Eschenbach 2012). Caribou (*Rangifer tarandus*), Canada Lynx (*Lynx canadensis*), North American Black Bear (*Ursus americanus*), River Otter, and American Marten (*Martes americana*) were all extirpated from PEI following European settlement (Sobey 2007). Although Caribou in Nova Scotia were extirpated by 1921 (Benson and Dodds 1977), none were reported after 1765 in PEI. Human exploitation was also responsible for the loss of Walrus (*Odobenus rosmarus*) from the Gulf of St. Lawrence beginning in the 1500s (McLeod *et al.* 2014), and Great Auk (*Pinguinus impennis*) became extinct in 1844, aided in part by their exploitation at Bird Rock in the Magdalen Islands, Quebec (Montevecchi and Kirk 1996).

Cameron (1958) contended the beaver was "exterminated" from PEI, and the data presented here support its status as native, at least since 500 AD and possibly as early as 9500 years BP. Evidence that might allow determining the point of extirpation is less clear, but it is almost certain that a beaver population was no longer present in PEI after 1860. It may well have been the first mammal extirpated from PEI, before 1700. Although the current beaver population is known to be derived from animals introduced from NB, it is also possible that some individual beavers have reached PEI via natural dispersal from NS or NB and could account for the late 19th century records from PEI. Future genetic studies may shed light on whether NS beavers have contributed to the current gene pool. In addition, and considering there are no known endemic species in PEI because of its geologically recent land connection with the mainland, beavers sourced from NB are predicted to be similar genetically to the original PEI population. It may be possible to test this using more archaeological remains of beavers as they become available. Additional radiocarbon dating of beaver incisors from middens may also reveal new information. Finally, because beaver-chewed sticks were seen as an indication that beavers were native mammals (Cameron 1958), monitoring bogs that are being mined for peat might yield older beaver records.

Although the founders of the current population were introduced to support fur harvesting (Dibblee 1994), the population meets International Union for the Conservation of Nature guidelines as a reintroduction, being "the intentional movement and release of an organism inside its indigenous range from which it has disappeared" (IUCN/SSC 2013: 2). We suggest that the American Beavers now extant on PEI be regarded as a native population and that the provincial government apply the precautionary principle in the unlikely event that population decline threatens the species. The second-growth riparian forests of PEI provide suitable beaver habitat and the beaver has populated most of the island. It is likely that human conflicts with beavers and their dams will occur as long as beavers flood transportation corridors and are viewed as negatively influencing spawning success of salmonids.

Author Contributions

Original Draft: R.C.; Writing – Review & Editing: R.C., D.L.K., H.E.K., and R.L.D.; Conceptualization: R.C.; Investigation: D.L.K., H.E.K., R.C., and R.L.D.; Methodology: R.L.D.; Formal Analysis: D.K. and R.L.D.; Funding Acquisition: H.E.K. and R.L.D.

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Sixty years of White-tailed Deer (*Odocoileus virginianus*) yarding in a Gray Wolf (*Canis lupus*)–deer system

L. David Mech[1,2,*] and Shannon M. Barber-Meyer[1,3]

[1]United States Geological Survey, Northern Prairie Wildlife Research Center, 8711 - 37th Street SE, Jamestown, North Dakota 548401-7317 USA
[2]United States Geological Survey, The Raptor Center, 1920 Fitch Avenue, St. Paul, Minnesota 55108 USA
[3]United States Geological Survey, 1393 Highway 169, Ely, Minnesota 55731 USA
[*]Corresponding author: david_mech@usgs.gov; mechx002@umn.edu

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Abstract

This article synthesizes information from over a six-decade period of studies of White-tailed Deer (*Odocoileus virginianus*) use of a winter yard and subject to Gray Wolf (*Canis lupus*) predation in northeastern Minnesota. It also adds spring migration data from 35 adult female deer and fawns studied there during 1998, 1999, 2001, 2014, and 2017. Twenty-nine of these deer migrated in spring a mean distance of 29 km (SE = 4), a maximum distance of 78 km, and at a mean bearing of 83° (SE = 12; range 21–348). These findings are similar to those from 49 deer (both sexes) from the same yard studied during 1974–1984, that migrated a mean distance of 25 km (SE = 1.8) and a mean bearing of 77° ± 4 SE. Between the two periods, the wolf population fluctuated considerably, the winter range of deer in the area where these deer spent summer greatly diminished, and both derechos and fires disturbed the habitat. This study attests to the selective advantage of the migratory tradition of deer in this yard.

Key words: *Canis lupus*; deer yard; migration; *Odocoileus virginianus*; predation; predator-prey relations; White-tailed Deer; wolf; yarding

Introduction

White-tailed Deer (*Odocoileus virginianus*) migrate between summer and winter ranges in many northern areas (summarized by Nelson 1998). Two main drivers of these migrations have been proposed: (1) the need for optimal protection from adverse winter weather (Townsend and Smith 1933; Severinghaus and Cheatum 1956; Ozoga 1968) and (2) grouping to minimize predation risk (Nelson and Mech 1981, 1991; Messier and Barrette 1985).

Most studies of migratory deer populations have been short term, describing migration distances, timing, and triggers for seasonal movements. One exception is an investigation of deer movements in southeastern Quebec that also depicted the extent of two deer yards over three decades (Lesage *et al.* 2000). Studies of deer migratory behaviour in areas where Gray Wolves (*Canis lupus*) are the primary predator of deer have been conducted for as long as 10 years (Forbes and Theberge 1995; Theberge and Theberge 2004), 15 years (Fieberg *et al.* 2008), and 28 years (Hoskinson and Mech 1976; Nelson and Mech 1981, 1987; Nelson 1995, 1998; Nelson *et al.* 2004). However, we know of no migratory White-tailed Deer herd subject to wolf predation that has been investigated for more than three decades.

As part of a long-term study of wolf ecology and population trend in northeastern Minnesota (Mech 2009), we have also researched White-tailed Deer there since 1964 (Mech and Frenzel 1971; Hoskinson and Mech 1976; Nelson and Mech 1981, 1987; Nelson 1998; Nelson *et al.* 2004). During that time, the amount of winter range of the deer herd we studied diminished greatly (Mech and Karns 1977). Forty-five years later, some 3000 km^2 that deer previously used for decades during winter remained devoid of wintering deer (Nelson and Mech 2006), and most, and probably all, of it still remains devoid of wintering deer (Mech *et al.* 2018). In addition, various habitat disturbances and other important changes detailed below have occurred in the wolf study area.

The wolf study area (Figure 1) lies in northeastern Minnesota, USA at about 47.60°N to 48.7333°N and 90.8167°W to 91.8333°W excluding the northwest quarter of that region and includes much of the Garden Lake deer yard (GLY) along its western edge

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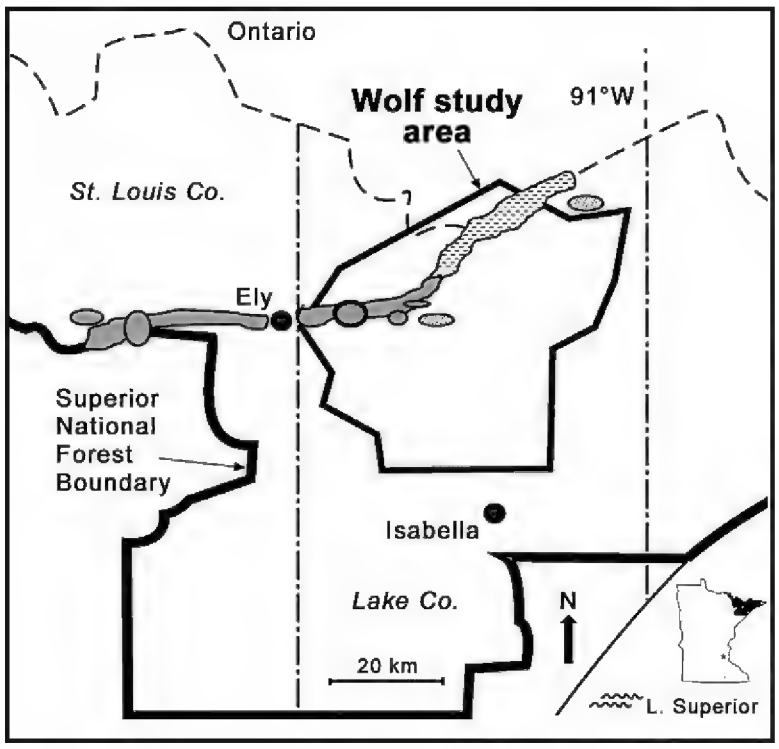

FIGURE 1. The wolf study area with the Garden Lake Yard (GLY). Irregular grey and stippled areas represent the GLY as described by Mech and Karns (1977). Grey and stippled ovals represent areas listed as deer yards by Arnold *et al.* (1961). Stippled areas (both irregular and oval) are where deer have not overwintered since the early 1970s (Mech and Karns 1977; Nelson and Mech 2006; Mech *et al.* 2018). The darker bold oval just east of Ely is the GLY proper, where White-tailed Deer (*Odocoileus virginianus*) from previous studies mentioned in the Introduction and the present study were radio-collared. Inset map shows location of Superior National Forest (black) in Minnesota.

near Ely, Minnesota, USA. The GLY is named for the area around Garden Lake and the adjacent area near the Winton Hydroelectric Power Plant where wintering deer concentrate the most under the most severe conditions and where deer were fed artificially in the early 1970s and probably for some time before that. Deer have continued to concentrate in the GLY during winter and to migrate to summer ranges in and through the wolf study area for over 60 years. We studied the migratory behaviour of deer in this yard from 1974 through 1984 (Hoskinson and Mech 1976; Nelson and Mech 1981, 1987, 1991; Nelson 1998) and again during 1998 through 2017. We document here the continued winter concentration of deer in that yard and their annual migrations despite those changes and despite a wolf population that depends on them for most of their diet (Barber-Meyer and Mech 2016). We also compare 1998–2017 demography and migratory status of the deer in that yard with results from 1974–1984 (Nelson and Mech 1981, 1987). The objective of this study is to demonstrate the extreme degree to which a migratory tradition in a given deer yard under natural conditions of wolf predation can persist, a record duration to our knowledge, and to compare the migratory behaviour over the period of this study.

Study Area

The extent of the GLY over the years has been described variously, no doubt because (1) deer populations fluctuate greatly over the decades, and (2) deer use of winter range, and thus their migration movements, vary considerably by season, temperature, and snow conditions (Nelson 1995). As these conditions change, deer may move toward or away from winter yards, sometimes wintering for long periods only partly along their route to areas where they would concentrate more during the most extreme conditions (Nelson and Mech 1981). The Pohenegmook and Lac Temiscouata deer yards in southeastern Quebec, Canada provide a good example of such changes (see Figure 3 in Lesage *et al.* 2000).

In 1953, the GLY was thought to encompass 128 ha, not including other yards west and east-northeast of the GLY (Erickson *et al.* 1961). Mech and Karns (1977) considered the GLY more inclusively, stretching from about 35 km west-southwest of Ely to Ely, about 25 km east of Ely, and then northeast about 12 km, totalling about 72 km long, and centring on the Garden Lake area (Figure 1). In the mid-1970s the GLY was thought to extend about 16 km east-northeast (Hoskinson and Mech 1976) and later as holding ≤800 deer (Nelson and Mech 1987). East of Garden Lake, deer currently continue to winter along the area that Hoskinson and Mech (1976) described at times as far as some 18 km east of Garden Lake.

Whether deer wintering elsewhere in the more expansive GLY other than those from the capture area (Nelson and Mech 1981, 1987, this study) migrate in the same direction to summer ranges as those deer radio tracked is unknown.

The GLY lies along the western edge of our long-term wolf study area (Mech 2009) which covers about 2060 km^2 including the migration routes along which the wintering GLY deer travel to their summer ranges (Figure 1). The wolf study area is situated well within the Minnesota wolf range (Fuller *et al.* 1992), and wolves have never been extirpated from the wolf study area. The area is replete with lakes and waterways, and American Beaver (*Castor canadensis*) and Moose *(Alces americanus*) are also available to wolves there (Mech and Karns 1977; Barber-Meyer and Mech 2016; Mech *et al.* 2018). Black Bear (*Ursus americanus*) is the only other major predator of deer in the region (Kunkel and Mech 1994), although Coyote (*Canis latrans*), Fisher (*Martes pennant*), Bobcat (*Lynx rufus*), and Canada Lynx (*Lynx canadensis*) inhabit the area and could prey on fawns. General habitat, topography, and weather in the study area were described by Nelson and Mech (1981, 2006) and Heinselman (1996).

In July 1999, a derecho windstorm leveled about 1600 km^2 of the forest through which some of the GLY deer migrate (National Oceanic and Atmospheric Administration 1999; Nelson and Mech 2006). Another derecho struck in 2016 that also affected the migration routes of these deer (Minnesota Department of Natural Resources 2016).

In 2000 and 2007, fires burned 431 km^2, just northeast beyond where radio-collared GLY deer migrate to but which could include summer ranges of other GLY deer (Fites *et al.* 2007). In 2011, the Pagami Creek fire burned 376 km^2 in which some GLY deer summered, or through which they migrated (Nelson and Mech 1987). Other habitat changes during the study included forest maturation, and alterations and variation in logging practices from clear cutting to total protection.

Weather conditions also changed considerably throughout the study. Snow depth, density, and persistence, especially during the past decade, differed from earlier in the study, including winter 2010–2011 when snow depth was extremely low and winter 2013–2014 when snow was very deep and fluffy.

White-tailed Deer have inhabited the region for many decades. Johnson (1922) considered deer common from 1912 to 1915. In 1938, Olson (1938: 330) published a map showing deer present in every township in the wolf study area. From 1948 to 1952, Stenlund (1955) documented wolf-killed deer in winter on most of the major lakes there. Erickson *et al.* (1961) stated that deer were abundant in the Northern Forest Zone, which included our wolf study area, for more than 40 years, and those authors listed 16 winter yarding areas they checked in or near our wolf study area between 1949 and 1958. Estimated deer densities in the Northern Forest Zone (although not necessarily in our wolf study area) ranged from 5.9 to more than 7.8/km^2 in the late 1930s (Erickson *et al.* 1961).

By the mid-1970s, almost no deer spent winter in the northeastern third of the wolf study area, and wolves there lived primarily on Moose and probably beavers (Mech and Karns 1977). Deer that had wintered there had succumbed to a combination of deteriorating habitat (maturing forests), a long series of severe winters, and heavy wolf predation (Mech and Karns 1977). Deer have not been observed overwintering there since, despite regular winter flights (Nelson and Mech 2006; Mech *et al.* 2018). Deer numbers along the southern and western edges of this area dropped to about 0.8 deer/km^2 (Floyd *et al.* 1979) and in 2011 pre-fawn densities averaged <2/km^2 (Lenarz and Grund 2011). To the east of the wolf study area, deer migrated during autumn to winter yards along the shore of Lake Superior (Nelson and Mech 1981) and reached yarding densities during 1968–1976 of 39 to 55/km^2 (Mech and Karns 1977). Deer from those yards moved at least 22 km northwest inland (Morse and Zorichak 1941; Nelson and Mech 1981).

Deer that wintered in yards along the west side of the wolf study area, primarily in and around Garden Lake, 8.8 km east-northeast of Ely, migrated in spring southeastward to northeastward for up to 54 km at a mean bearing of 77° (Nelson and Mech 1987).

Moose have also occupied the region for many decades. Johnson (1922) found Moose very common in 1912–1915 but scarce in 1920. Olson (1938) estimated a Moose density of 1/6.4 km^2 based on his observations during 1920–1936 and his discussions with various wardens, trappers and other woodsmen, but Stenlund (1955: 22) considered their numbers "not high" during 1948–1952. An historical estimate of Moose density from 1915 to 1970 over the entire northeastern Minnesota Moose range, which included our wolf study area, was 1/3.8 km^2 to 1/21.9 km^2 (Peek *et al.* 1976). From 1984 to 2016 in this Moose range, densities based on annual aerial counts were 1/1.7 km^2 to 1/5.5 km^2 (calculated from Moose-count data; Mech *et al.* 2018). Moose numbers in the overall northeastern Minnesota Moose range peaked in 1989, 1996, and 2006, declined to less than half their 2006 level by about 2012, and then leveled off for several years (DelGiudice 2017; Mech *et al.* 2018).

Wolves have inhabited the region throughout recorded history (Olson 1938; Stenlund 1955; Mech and Frenzel 1971). Wolf numbers in the wolf study area varied from 23–32 in winter 2016–2017 (L.D.M. and S.M.B.-M. unpubl. data) to 97 in 2008–2009, a density ranging from 11–16/1000 km^2 to 47/1000 km^2 during 1968–2017 (Mech 1973, 1986, 2009; Mech *et al.* 2018). During and after the major deer decline in the 1970s, wolf numbers there also declined considerably and did not reach former levels until about 2000 after recovering from a prolonged infection by canine parvovirus (Mech *et al.* 2008). A few years after Moose numbers began declining in 2006 and deer numbers declined due to severe winters, the wolf population began dropping to its lowest level during the study, 23–32 animals (Barber-Meyer and Mech 2016; Mech *et al.* 2018).

The primary migration routes and many of the summer ranges of the GLY deer we studied usually fell within the territories of two wolf packs, known as the Wood Lake and Ensign Lake Packs in earlier publications (Mech 1973, 1986). Over the decades, the actual locations of these pack territories varied considerably, and other packs that used parts of the GLY, the deer migration routes, or the summer ranges of the GLY deer formed and disintegrated as well. At times, as many as four radioed packs, totalling up to 29 members during winter used the GLY (L.D.M.,

S.M.B.-M., and M.E. Nelson unpubl. data). In addition, wolf packs sometimes inhabited the GLY year around. One such pack that inhabited 39 km^2 including Garden Lake itself hosted the highest wolf density ever recorded anywhere, 182 wolves/1000 km^2 during winter, from 1 April 1998 through 30 March 1999 (Mech and Tracy 2004).

Based on 39 years during which the Wood Lake Pack was radio-collared and 24 years in which the Ensign Lake Pack was radio-collared between 1973 and 2017, their winter pack sizes averaged 5.3 ± 0.41 SE and 5.6 ± 0.55 SE and ranged up to 11 and 12 members, respectively (L.D.M., S,.M.B.-M., and M.E. Nelson unpubl. data). The numbers of wolves in these packs did not follow the trajectory of the overall wolf numbers in the wolf study area, but rather remained relatively constant from winter 1973–1974 through about 2006, although they declined after that (Mech 1973, 1986, 2009; L.D.M.,S.M.B.-M., and M.E. Nelson unpubl. data). In any given year, the packs that used the area including the GLY deer summer ranges and migration routes usually migrated to the Garden Lake area itself during autumn and back to the deer summer ranges in spring (Mech and Boitani 2003; L.D.M. and S.M.B.-M. unpubl. data) except when resident packs resided year around there.

Methods

Using Clover traps from 1998 to 2017, we live trapped, anesthetized, ear tagged, and radio collared deer within 1.4 km of the GLY (Mech and Barber-Meyer 2020). Three others were captured near Snowbank Lake, some 23 km east northeast of Garden Lake but still in the more expansive definition of the GLY discussed above. In the current study we excluded the three Snowbank Lake deer (included in a study by Nelson *et al.* [2004]) because that area was not included in the Nelson and Mech (1987) area with which we compare our data. Our GLY captures were basically in the same area where deer (both sexes) from this yard were studied earlier (Hoskinson and Mech 1976; Nelson and Mech 1981, 1987). We extracted an incisor from adults for aging by Matson's Laboratory (Missoula, Montana, USA). We located the deer by aerial radio tracking or by global positioning system (GPS) collar locations during June, July, and August until at least two consecutive locations were in the same general area to determine their summer ranges (because generally once on summer range they remain in a relatively small area [Nelson and Mech 1999]) and again each winter when they returned to the winter yard (Nelson *et al.* 2004). We examined the approximate spring migration routes of deer collared with prototype Advanced Telemetry Systems (Isanti, Minnesota, USA) drop-off GPS radio collars (details in Merrill *et al.* 1998), including some studied by Nelson *et al.* (2004).

We plotted individual deer summer locations and a summary location representing the centre of the winter deer capture locations on Google Earth Pro 7.1.7.2606 and measured the migration distances and directions via the Google Earth Tool function after converting UTMs of these locations to latitudes and longitudes via "Convert Geographic Units online" (http://www.rcn.montana.edu/resources/converter.aspx). Although fawns captured during the same year and at the same location as an adult female and migrating to the same summer range as the adult (or not migrating but remaining at the same summer range as the adult) might have been fawns of the adult, we still included the fawns as independent data. We used Statistix 9.0 (2008) to compare migratory status (including fawns) between our 1998–2001 and our 2014/2017 results using Fisher's Exact Test, respectively, and also to those from a previous study in the same area (Nelson and Mech 1981, 1987). We compared age structures (excluding fawns) between 1998–2017 and those from the previous study (Nelson and Mech 1981, 1987) via the Mann-Whitney *U*-test in R version 3.5.1 (R Core Team 2018). We considered all differences significant at alpha = 0.05.

Results

We live-trapped and radio-collared 27 adult does and eight fawns during winters 1998–2001, 2014, and 2017 in or near the GLY and aerially radio-tracked them to their summer ranges (Table 1), including eight whose spring migrations were studied in detail by Nelson *et al.* (2004). Apart from fawns, their mean age was 6.3 (SE = 0.8) years (Figure 2). All of the 19 deer we radio-collared in 1998–2001, including fawns, migrated to summer ranges, but six (including two fawns) of the 16 that we followed in 2014 and 2017 remained during summer within 3 km of their winter capture point, a significant difference between these two periods (Fisher's Exact = proportion

TABLE 1. Female White-tailed Deer (*Odocoileus virginianus*) or fawns of either sex radio-collared (first capture only) in Garden Lake Yard, Ely, Minnesota, USA, 1998–2017 and radio-tracked to their summer ranges. Six deer did not migrate.

Year	*n* (# fawns)	Age (year)*	
		Mean	Range
1998	8 (2)	5.6	3–11
1999	5 (0)	7.2	1–13
2001	6 (1)	3.7	1–13
2014	4 (1)	6.3	5–8
2017	12 (4)	7.1	2–13
1998–2017	35(8)	6.3	1–13

*27 adults and yearlings; excludes two adults of unknown age.

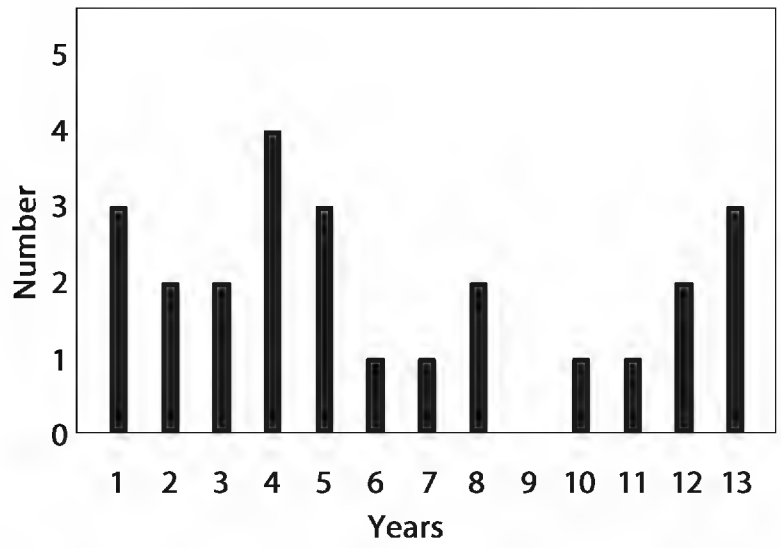

FIGURE 2. Age structure of adult and yearling female White-tailed Deer (*Odocolieus virginianus*) live-trapped (first capture only), in or near the Garden Lake Yard, Minnesota, 1998–2017, radio-collared, and followed to summer range.

difference 0.375, $P = 0.005$). The mean age of the four adult non-migrating deer was 7.3 and that of the 21 non-fawn migrators was 6.1. The age structures of the groups did not differ (W = 33, $P = 0.53$).

The 35 adults and fawns migrated in spring a mean distance of 29 km (SE = 4), a maximum distance of 78 km, and at a mean bearing of 83° (SE = 12; range = 21–348) excluding the six non-migrators (Table 2; Figure 3). Although the deer during different years of the study varied in the distances and directions to which they migrated, most of the annual mean migration distances were 21–36 km, and most of the annual mean migration bearings were 58–90° (Table 2). The 114° mean bearing for five deer in 1999 was heavily influenced by one deer whose migration bearing was 348°. Excluding that deer, the mean bearing was 55° (SE = 14). Notably, two other deer captured in the same general location as deer that migrated east-northeastward migrated in markedly different directions southwest, and south. Excluding all three deviant deer, and the non-migrators, the mean summer migration bearing was 65° (SE = 4; $n = 26$), the basic direction that the GLY extended. The mean migration distance of this sample was 29 km (SE = 4; 4–78 km).

Discussion

The sample of 35 does and fawns we studied from 1998 through 2017 generally was similar to that of the does and fawns studied from 1974–1984 in the same area (Nelson and Mech 1981, 1987). We compared these two periods (19 and 10 years long) because those were the periods for which we had comparable data. There was no significant difference in the radio-collared doe:fawn ratios (37:19 versus 39:28) between the early and later capture samples (Fisher's Exact = proportion difference 0.079, $P = 0.46$). The mean age of adult does of the earlier sample was 5.0 years and that of the later sample was 6.3 years. The age structures of the groups did not differ (W = 359, $P = 0.24$). The 1998–2017 sample of does and fawns that we followed through spring migration migrated similarly in mean distance (25 km ± 1.8 SE) to those from 1974–1984, but not maximum (78 km this study versus 54 km, measured from Nelson and Mech [1987: Figure 2.2]). They were also similar in the general directions they migrated (77° ± 4 SE; Nelson and Mech 1987). Of the 49 GLY deer (18 males: 31 females) whose spring migrations were studied from 1974 to 1984, 42 migrated (Nelson and Mech 1987), and with our 1998–2017 sample of 35 does and fawns, all except six migrated, a non-significant difference between proportions of migrators during the two periods (Fisher's Exact = proportion difference 0.029, $P = 0.77$).

The demography and migration we studied in the sample of deer wintering in the GLY differed little

TABLE 2. Migration distance and direction of White-tailed Deer (*Odocoileus virginianus*) that were radio-collared during 1998 through 2017 and followed to their summer ranges. Fawns possibly of collared does were included separately.

Year	No. of deer	No. migrating	Summer migration				Remarks
			Distance (km)		Direction (°)		
			$\bar{x}$ ± SE	Maximum	$\bar{x}$ ± SE	Range	
1998	8	8	36 ± 6	62	64 ± 8	26–97	
1999	5	5	31 ± 4	45	114 ± 60	21–348	
2001	6	6	26 ± 10	58	78 ± 17	39–153	
2014	4	1	2 ± 2	8			Includes three non-migrators
2014	4	1	8	8	58	—	Excludes three non-migrators
2017	12	9	21 ± 7	78			Includes three non-migrators
2017	12	9	28 ± 7	78	90 ± 18	36–226	Excludes three non-migrators
1998–2001	19	19	31 ± 4	62	81 ± 16	21–348	
2014–2017	16	10	16 ± 5	78			Includes six non-migrators
2014–2017	16	10	26 ± 7	78	87 ± 16	36–226	Excludes six non-migrators
1998–2017	35	29	24 ± 3	78			Includes six non-migrators
1998–2017	35	29	29 ± 4	78	83 ± 12	21–348	Excludes six non-migrators

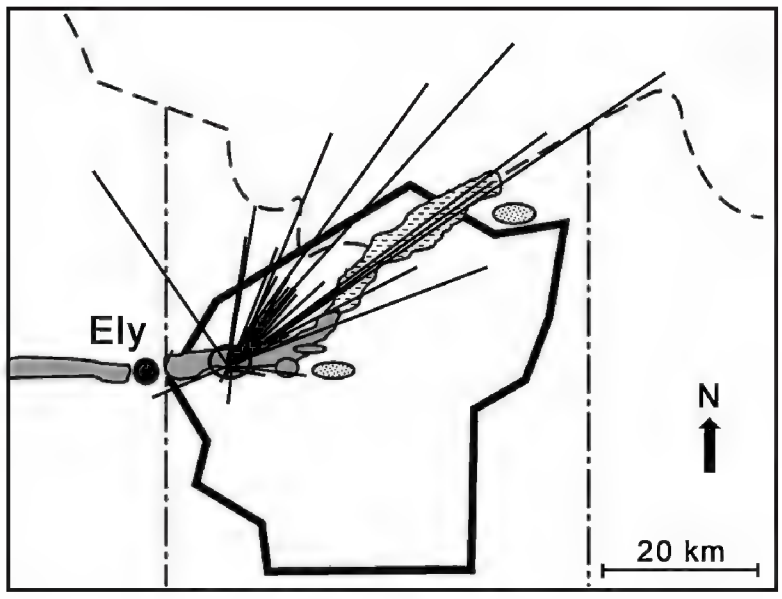

FIGURE 3. Distances and directions of spring migrations of 29 adult female and fawn White-tailed Deer (*Odocolieus virginianus*) radio-collared in the Garden Lake Yard during five winters between 1998 and 2017 (Table 1). Six of the original sample of 35 did not migrate.

from those studied there during 1974–1984. During the interim, several important environmental changes took place, as discussed in the Introduction.

Throughout this period and despite the changing deer, Moose, and wolf populations, as well as the widespread habitat upsets (e.g., derechos, forest fires, snowpack differences, changes in forestry practices), the majority of GLY deer continued to migrate each winter to the GLY the way they have for decades. Furthermore, we cannot extrapolate our findings to other migrating ungulate-wolf systems and would expect each deer yarding situation to be different because each local yarding ecology will be different.

Nelson (1995, 1998) and Nelson *et al.* (2004) provided details of the earlier migrations. The wolves that inhabited the major portions of the GLY deer summer and winter ranges maintained their numbers through about 2006. After Moose began to decline in 2006, the number of these wolves decreased, but packs continued to migrate each year for which we had data, presumably in response to the deer migration (L.D.M. and S.M.B.-M. unpubl. data), similar to wolf packs in Algonquin Park, Ontario, Canada (Forbes and Theberge 1995; Theberge and Theberge 2004).

During summer, the major age class of deer that local wolves kill are fawns (Nelson and Mech 1986; Barber-Meyer and Mech 2016), although the availability of beavers and Moose might buffer that predation (Mech and Karns 1977; Barber-Meyer and Mech 2016). Evidence from other parts of the wolf study area suggests that individual fawns are visited by wolves on average in summer about 5.5 times/100 days (Demma and Mech 2009) to daily (Mech *et al.* 2015), although the rate of fawn predation is unknown. Regardless, even though fawns comprise a high percentage of the diet of wolves in summer (Barber-Meyer and Mech 2016), enough fawns have survived in the summer ranges of the GLY deer each year to sustain the migrating deer population over the decades.

GLY migrating deer spend 31–356 hours during migration and adhere closely to a straight line during the trip (Nelson *et al.* 2004). While migrating, deer are much more vulnerable to wolf predation than at any other time as adults (Nelson and Mech 1991), so the persistence of GLY deer either abandoning summer range or favouring winter range or both during winter must have some strong adaptive value. Reducing vulnerability to wolf predation during winter when deer are in poor nutritional condition (DelGiudice *et al.* 1992) and hindered by snow conditions (Mech *et al.* 1971) was the explanation Nelson and Mech (1981) gave for deer in this area migrating to areas of high deer density, i.e., the GLY, listing several advantages to yarding. This benefit was one of the points Nelson and Mech (1981) proposed as an anti-predator effect of yarding. We further note that Poszig and Theberge (2000) did find that non-yarding deer in their study were "highly vulnerable" when migrating wolves returned to their territory.

Kolenosky (1972) had already shown that wolves tended to kill deer along the edges, rather than the centre of the deer yards he studied, and further support for the antipredator explanation for deer migration and yarding has since been found in other studies. In northwestern Minnesota, wolves also tended to kill deer along the edges of yarding areas rather than in the densest areas (Fritts and Mech 1981) as did Coyotes in Quebec (Messier and Barrette 1985).

On the other hand, Poszig and Theberge (2000) found evidence in Ontario that tended to dispute the hypothesized antipredator advantages of deer yarding. The only benefit of yarding they proposed would be an enhanced trail network through the snow that might give deer in high densities more of an advantage in escaping wolves.

Henderson *et al.* (2018) emphasized the role of density-dependent competition for home ranges in winter that forced deer to space out during summer to obtain adequate nutrition. The spacing out of migrating deer to their summer ranges, where their fawns are born, provides far more habitat per deer to obtain nourishment, with summer being the season of annual replenishment (Silver *et al.* 1969; Moen 1978; DelGiudice *et al.* 1992). However, it also brings several other survival benefits related to wolf predation: (1) familiar escape terrain and habitat; (2) an area with a proven history of survival characteristics; and (3) separation from other fawns that would attract

predators. Fawns are most vulnerable during late spring and early summer (Kunkel and Mech 1994; Carstensen *et al.* 2009), so widely spaced fawns reduce the chance that any individual fawn would be detected by predators, thus increasing survivability (although reducing potential benefits of group vigilance and defense).

None of these benefits of return to summer range or migration to winter range (Nelson and Mech 1981) conflict with the Henderson *et al.* (2018) findings, for in complex ecosystems both foraging and predation risk are factors between which animals must find trade-offs that enhance their survival (Lima and Dill 1990). Within the context of these trade-offs, our study demonstrates that, in an area where wolf predation is the major natural mortality for adult deer, long deer migrations between winter and summer ranges and yarding in winter produces strong enough survival value for the behaviour to have persisted for over six decades and many generations.

Author Contributions

Writing – Original Draft: L.D.M.; Writing – Review & Editing: L.D.M. and S.B.-M.; Conceptualization: L.D.M.; Investigation: S.B.-M.; Methodology: L.D.M.; Formal Analysis: L.D.M. and S.B.-M.; Funding Acquisition: L.D.M.

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Nest site characteristics of cavity-nesting birds on a small island, in Haida Gwaii, British Columbia, Canada

Neil G. Pilgrim[1,*], Joanna L. Smith[1,2], Keith Moore[1], and Anthony J. Gaston[1]

[1]Laskeek Bay Conservation Society, P.O. Box 867, Queen Charlotte City, British Columbia V0T 1S0 Canada
[2]Nature United, 366 Adelaide Street East, Suite 331, Toronto, Ontario M5A 3X9 Canada
*Corresponding author: biologist@laskeekbay.org

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Abstract

Many studies of cavity-nesting birds in North America are conducted in large continental forests and much less is known about them in island ecosystems. We describe a 29-year study of tree species, nest site characteristics, and fledge dates of cavity-nesting birds on a small island in Haida Gwaii, British Columbia (BC). Seven cavity-nesting bird species were documented on East Limestone Island and 463 nests were found in 173 different trees. Nest trees were significantly taller and had a greater diameter than a random sample of snags. Tree height did not differ among bird species but diameter at breast height was larger for trees used by Brown Creeper (*Certhia americana*) than for other species. Cavity-nesters selected tree decay classes 2–7 (all dead/near dead [snags]), with 85% in decay class 4 (35%) or 5 (50%), similar to the random snag sample (class 4, 32%; class 5, 42%). Cavity height ranged from 2.6 to 44.9 m and for all species, except Brown Creeper, the mean nest height was >60% of the mean tree height. Nest heights were generally greater than observed elsewhere in BC. Nest cavity orientation was random except for Red-breasted Sapsuckers (*Sphyrapicus ruber*), for which only 13% of the cavity entrances faced southeast. Median fledging dates ranged from 7 June (Chestnut-backed Chickadee [*Poecile rufescens*]) to 28 June (Northern Flicker [*Colaptes auratus*]). Estimated median dates of clutch completion were similar for all species. Our results show that large snags provide habitat for a high diversity of cavity-nesting birds on Haida Gwaii.

Key words: Wildlife trees; cavity-nesters; excavators; nest site; timing of breeding

Introduction

Dead and dying trees are essential for creating high quality nest sites for cavity-nesting birds (Li and Martin 1991) and primary excavators (those species that normally excavate new nest sites each year) are essential to many secondary species in providing the necessary conditions for them to nest or find shelter (Aitken and Martin 2007). Many factors can contribute to nest-site quality including tree height, nest height, nest-hole orientation, and the state of tree decay (McClelland and Frissell 1975; Inouye 1976). The selection of a nest tree and characteristics of nest sites are known to contribute to the reproductive success of cavity-nesters by affording protection for the breeder and their offspring from predators and improved microclimate in the nest cavity (Von Haartman 1957; Wesołowski 2002; Maziarz and Wesołowski 2013).

Cavity-nesting birds can be divided into three groups related to how they acquire their cavity: (1) primary cavity-nesters excavate their own holes in live or dead trees and typically excavate a new hole each year, (2) secondary cavity-nesters use holes excavated by other species (usually primary cavity nesters), use a naturally occurring hole and may re-use nests, and (3) weak cavity-nesters either make their own hole in a heavily decaying tree, nest in a cavity excavated by another species, or expand a naturally occurring hole. A bark nester, Brown Creeper (*Certhia americana*), has also been included in this paper, though it mainly nests under loose bark (Davis 1978).

Nest site characteristics vary among and within bird species by geographic location and forest type (Scott *et al.* 1977; Newton 1994). Characteristics of cavity-nests most often reported include nest tree species, height, diameter, state of decay (or decay class), height of the nest site above the ground, and the cardinal direction of the cavity entrance. Most studies examined these characteristics for continental forests (e.g., Carlson *et al.* 1998; Martin *et al.* 2004; Vaillancourt *et al.* 2008), usually in relation to forest management guidelines in order to maintain stand structure to support cavity-nesters (e.g., Steeger and Dulisse 2002). Few studies have examined these

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characteristics in small island ecosystems. These may differ from continental ecosystems in having fewer suitable nest sites due to the limited forest area available and/or having more pronounced edge to interior effects, thus increasing risks from predation.

The purpose of our study was to identify nest site characteristics of cavities as well as timing of breeding for all regularly-occurring cavity-nesting species on a small island in Haida Gwaii. Nest site characteristics were measured within the island's mature forest ecosystem by researchers and citizen scientists of the Laskeek Bay Conservation Society (http://www.laskeekbay.org), a local non-profit organization founded in 1990, with a well-established annual field program. We examined characteristics of nest trees selected by cavity-nesters and compared them with a random selection of available trees. We also compare the results from our island study to other ecosystems and discuss the likely selection pressures governing nest site choice in this ecosystem.

Study Area

Data were collected on East Limestone Island, Haida Gwaii, British Columbia (BC), Canada (52.90747°N, 131.613°W), a 48 ha island located in Laskeek Bay in the K'unna Gwaay heritage site/conservancy. It is adjacent to the southeast tip of Louise Island (27 200 ha) and is separated from it by only 400 m at the closest point. The island is mostly flat, or gently sloping, with the highest point of elevation being 65 m on the south ridge. Elevation gradients are most prominent along the east and west coasts where multiple coves lead to the sea via steep slopes. The northern coast of the island is the site of a large cove that encompasses most of that coast.

East Limestone Island is in the Coastal Western Hemlock Zone, wet Hypermaritime subzone, a BC biogeoclimatic category characterized by cool winters and mild, cool, wet summers with periodic dry warm spells (Banner *et al.* 2014). Strong winds are common and form an important climatic feature. Rainfall can exceed 1000 mm annually. The forest is primarily dominated by mature Sitka Spruce (*Picea sitchensis* (Bongard) Carrière), Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and Western Red Cedar (*Thuja plicata* Donn ex D. Don). Red Alder (*Alnus rubra* Bongard), Pacific Crabapple (*Malus fusca* (Rafinesque) C.K. Schneider), Sitka Alder (*Alnus alnobetula* ssp. *sinuata* (Regal) Raus), and Scouler's Willow (*Salix scouleriana* Barratt ex Hooker) are present along the shoreline and in a few places within the interior forest. The understorey is sparse due to shade from the mature trees and intense browsing by the invasive Black-tailed Deer (*Odocoileus hemionus*; Stockton *et al.* 2005). Although shrubs are sparse, they occur throughout the island and include *Vaccinium* species (Red Huckleberry [*Vaccinium parvifolium* Smith], Oval-leaved Blueberry [*Vaccinium ovalifolium* Smith]), Salal (*Gaultheria shallon* Pursh), and Red Elderberry (*Sambucus racemosa* L.).

The forest has not been commercially logged and most trees have been estimated to be more than 100 years old (K.M. pers. obs.). Like most temperate coastal old-growth systems, wind is a major factor for disturbance on the island, with windthrow the most common reason for gap creation and tree mortality (Pojar and MacKinnon 1994), in part due to shallow soils and high edge-interior effects. In 2010, a major windstorm hit Laskeek Bay and ~50% of the forest on East Limestone Island was blown down, resulting in high mortality for mature Western Hemlock and Sitka Spruce.

Methods

Nest location and monitoring

Between 1991 and 2018, staff and volunteers of the Laskeek Bay Conservation Society searched for and recorded cavity-nests on East Limestone Island. Observations were made of the tree characteristics, the nest cavities, and the species that occupied them. This comprised the "wildlife tree monitoring program", a citizen science effort involving numerous staff and volunteers each year from 1990 to 2018. Observations were made throughout May and June in all years and up to 9 July in all but five years (1990–1992, 2002, 2003, and 2011). From the beginning of the monitoring program, trees containing active nests were tagged with unique numbers and mapped. In 1990, observations were incidental to other work. The next year a systematic methodology to detect occupied breeding sites was designed and occurred annually using a written protocol. From 1991 to 1995, nests were located by listening for begging chicks during the nestling period. From 1996 onwards, all trees used at least once during the previous five years were included in that year's sample of nest trees and observed three times for 30 min in late April or May during the nest building, egg laying, and incubation phases of breeding. The observations were made, generally, within a few days of each other by one or two observers with binoculars situated at least 15 m from the nest tree. If no activity was observed after these three visits the tree was considered inactive for that season. If activity was observed, the tree was considered active and checked for 30 min every three days during June for evidence of breeding activity (e.g., adults feeding nestlings or chicks calling). Once chicks were heard calling, nests were checked every two days for 30 min (weather permitting) to deter-

mine when chick calling ceased, assumed to be a sign that the nestlings had fledged. Up to three times per season (late-May to mid-July) a survey of the entire 45 ha island was conducted to locate any new nest sites; the island was divided into four quadrants and four to six observers would spend several hours moving slowly throughout them, watching and listening for cavity nesting birds. Once active nests were confirmed and chicks were being fed, all the remaining wildlife trees that had been surveyed earlier in the season were visited again and monitored for 10 min to confirm vacancy—ensuring that no active nests had been missed. This protocol was thought to have a very high chance of success for the primary cavity nesters, as all have young that call loudly from the nest site and in every year, four to six observers were present on the island throughout the nesting season. However, our inventory was not likely to be complete for the other species, especially Brown Creeper, which has rather quiet young. All new nest trees were numbered, added to the monitored nest inventory, nest site characteristics measured and recorded, and location mapped. At the end of each season, any nest tree that had been inactive for five seasons was removed from the "active" inventory.

Fledging date was assigned to the average of the last date when chicks were seen or heard and the first date with no sound or visuals. Sightings of fledglings out of the nest were also used as an indication of fledging date. For species with 10 or more records of active nest sites on the island, the dates of the onset of incubation were estimated by taking the estimated date of fledging from the field surveys and subtracting incubation and fledging periods provided by the relevant species accounts in the Birds of North America (https://birdsna.org/Species-Account/bna/). Durations of incubation and fledging periods applied are given in Appendix 1.

Multiple characteristics were noted for each active nest tree: bird species, tree species, total tree height (m), percent cover bark (main stem), tree classification (including number of bracket fungi; see Guy and Manning 1995), nest cavity entrance height, tree diameter at breast height (dbh), and nest cavity orientation. These characteristics were recorded when a hole was first discovered and subsequently if any changes occurred (e.g., tree height). In this paper, we use the BC Tree Classification System (Guy and Manning 1995) to determine the current level of decay of each tree when first used. The BC Tree Classification System has nine categories, ranging from 1—live/healthy to 9—debris (Figure 1). The term snag refers to a standing dead or dying tree. British Columbia's Tree Classification class 2 is live/unhealthy and, in this paper, will be referred to as a snag. All the characteristics listed in BC Tree Classification System (Figure 1) were used to determine what decay class a snag was considered to be. If characteristics of different decay classes were found in one snag, the snag was classified according to the maximum number of characteristics.

Random sample of available nest trees

In July 2004, an island-wide survey was carried out to obtain a random sample of all possible trees available for cavity-nesters in decay class 2 or higher. We selected random trees at 50 m intervals along the two main trails on the island. At each interval, we took a 90° bearing, perpendicular to the trail, and

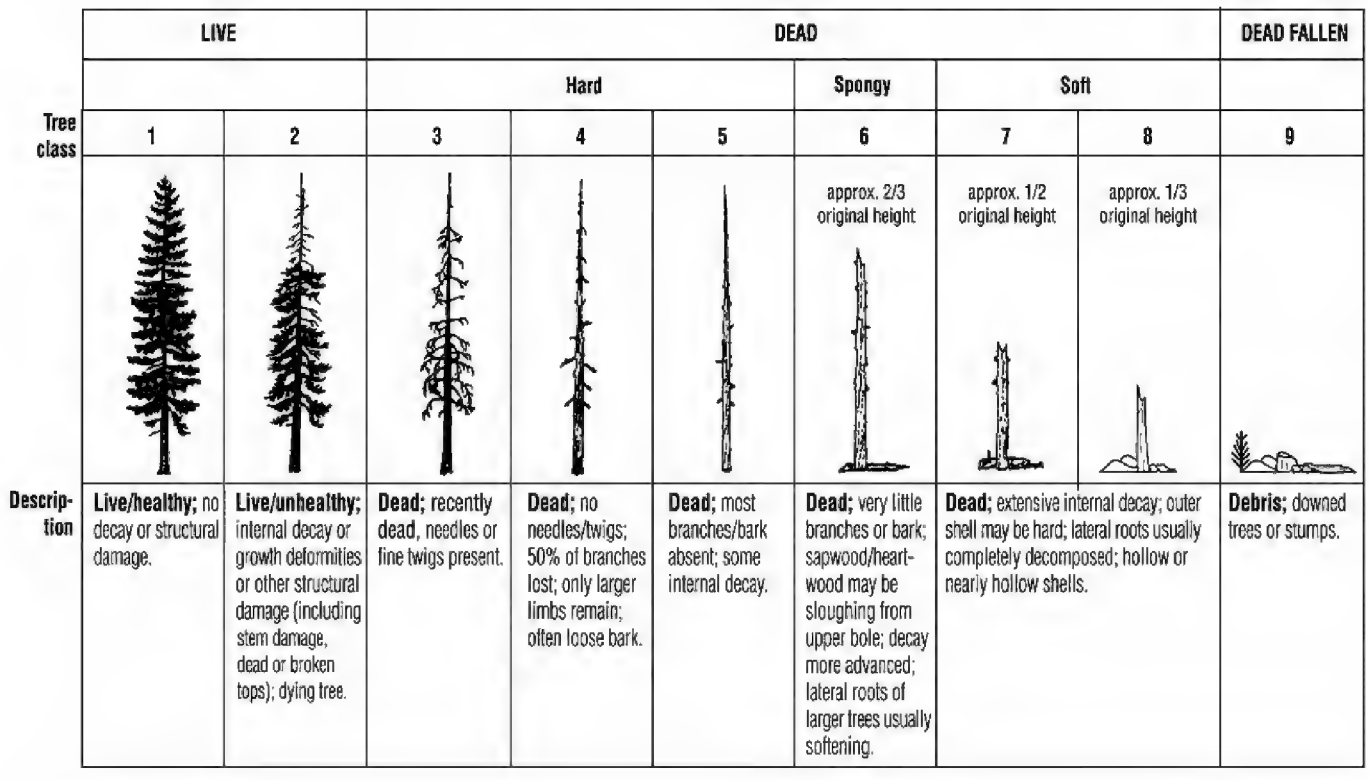
LIVE
DEAD
DEAD FALLEN
Hard
Spongy
Soft
Tree class
1
2
3
4
5
6
7
8
9
approx. 2/3 original height
approx. 1/2 original height
approx. 1/3 original height
Description
Live/healthy; no decay or structural damage.
Live/unhealthy; internal decay or growth deformities or other structural damage (including stem damage, dead or broken tops); dying tree.
Dead; recently dead, needles or fine twigs present.
Dead; no needles/twigs; 50% of branches lost; only larger limbs remain; often loose bark.
Dead; most branches/bark absent; some internal decay.
Dead; very little branches or bark; sapwood/heartwood may be sloughing from upper bole; decay more advanced; lateral roots of larger trees usually softening.
Dead; extensive internal decay; outer shell may be hard; lateral roots usually completely decomposed; hollow or nearly hollow shells.
Debris; downed trees or stumps.

Figure 1. British Columbia's Tree Classification System (Guy and Manning 1995).

laid out a 20 m transect, measuring all dead/near dead (decay class 2–8) trees that fell within ~5 m of either side of the transect. The same characteristics were recorded for these trees that were recorded for the occupied nest trees.

Statistical analysis

Five cavity-nesting species for which sample sizes were more than five were used in statistical comparisons: Red-breasted Sapsucker *(Sphyrapicus ruber)*, Hairy Woodpecker (*Dryobates villosus*), Northern Flicker (*Colaptes auratus*), Chestnut-backed Chickadee (*Poecile rufescens*), and Brown Creeper. The first three species are primary cavity-nesters and the fourth and fifth are, respectively, a weak excavator and a bark nester. For the analysis of tree characteristics used by cavity-nesters—tree height, tree species, dbh, and state of decay—we used the characteristics as described the first time that a tree was found in use by each bird species, regardless of how many years a nest tree was active. When analyzing individual nest height and orientation, all nests across all years were analyzed.

Most statistical analysis were conducted using PAST3 (Hammer *et al.* 2001) for Mac OSX: analysis of variance (ANOVA) with Tukey's pairwise tests were used to compare tree height, nest height, and dbh among the cavity-nesting species. A two-sample *t*-test was used to compare the trees used by cavity-nesting species to a random sample of trees of similar decay class for tree height and nest height. Statistical program R version 3.4.3 (R Core Team 2017) was used to conduct a Rayleigh test of uniformity to compare nest hole orientations among species. Means are given ± 1 SD. Some data were not recorded for some nests, so that sample sizes are not the same for all analyses.

Results

During our study, the island supported seven cavity nesting birds: three primary cavity nesters: Red-breasted Sapsucker, Hairy Woodpecker, and Northern Flicker; two weak excavators: Chestnut-backed Chickadee and Red-breasted Nuthatch (*Sitta canadensis*); a bark nester: Brown Creeper; and a secondary cavity nester: Northern Saw-whet Owl (*Aegolius acadicus*). A total of 463 nests were found in 173 different trees: Red-breasted Sapsucker ($n = 344$), Hairy Woodpecker (33), Northern Flicker (9), Chestnut-backed Chickadee (47), Red-breasted Nuthatch (9), Brown Creeper (19); and Northern Saw-whet Owl (2). The main excavator on the island was overwhelmingly Red-breasted Sapsucker, which occupied 74% of the cavity nests found.

Tree characteristics

We located and tagged 173 trees used by cavity-nesting birds between 1990 and 2018 (Table 1). Most of the cavity-bearing trees were Sitka Spruce (60%) or Western Hemlock (32%) with a small percentage of Red Alder (3%) and Western Red Cedar (1%), and a few of unknown identity, either because the species were missing in data records or the decay class did not allow species determination (4%; Table 2).

TABLE 1. Mean, SD, minimum and maximum tree heights, and tree diameters of bark nesting (Brown Creeper [*Certhia americana*]) and cavity-nesting birds and random sample of snags on East Limestone Island, Haida Gwaii, from 1990 to 2018.

	n	Tree height (m)			Tree diameter (dbh; cm)		
		Mean	SD	Range	Mean	SD	Range
Red-breasted Sapsucker (*Sphyrapicus ruber*)	130	22.7	10.4	7.2–52.8	104	40	40–260
Hairy Woodpecker (*Dryobates villosus*)	27	20.7	9.7	3.8–40.8	93	32	50–200
Northern Flicker (*Colaptes auratus*)	8	19.7	6.0	14.1–32.8	93	41	46–170
Chestnut-backed Chickadee (*Poecile rufescens*)	29	22.2	12.8	5.1–46.6	119	57	31–240
Red-breasted Nuthatch (*Sitta canadensis*)	5	21.5	7.5	15.4–33.9	104	32	68–154
Northern Saw-whet Owl (*Aegolius acadicus*)	2	12.6	3.6	10.0–15.1	96	49	61–130
Brown Creeper (*Certhia americana*)	16	22.4	13.7	7.2–58.5	133	54	54–260
All cavity-bearing trees*	173	21.7	11.1	3.8–58.5	104	43	31–260
Random selection of snags	100	12.6	11.1	1.3–63.3	62	46	11–229

*Total number of nest trees used throughout the study. These trees were used more than once by various bird species.

TABLE 2. Percentages of tree species used by various cavity-nesting birds on East Limestone Island, Haida Gwaii.

Species	Sitka Spruce (*Picea sitchensis*)	Western Hemlock (*Tsuga heterophylla*)	Red Alder (*Alnus rubra*)	Western Red Cedar (*Thuja plicata*)	Unknown
Red-breasted Sapsucker ($n = 130$) (*Sphyrapicus ruber*)	56.9	36.9	1.5	0.0	4.6
Hairy Woodpecker ($n = 26$) (*Dryobates villosus*)	65.4	34.6	0.0	0.0	3.9
Northern Flicker ($n = 8$) (*Colaptes auratus*)	75.0	12.5	12.5	0.0	0.0
Chestnut-backed Chickadee ($n = 29$) (*Poecile rufescens*)	79.3	17.2	3.5	0.0	0.0
Red-breasted Nuthatch ($n = 5$) (*Sitta canadensis*)	60.0	40.0	0.0	0.0	0.0
Brown Creeper ($n = 16$) (*Certhia americana*)	75.0	18.8	0.0	6.3	
Northern Saw-whet Owl ($n = 2$) (*Aegolius acadicus*)	100.0	0.0	0.0	0.0	0.0
All cavity-bearing trees ($n = 173$)	59.5	31.8	2.9	1.2	4.6
Random selection of snags ($n = 100$)	64.0	31.0	4.0	1.0	0.0

The percentage distribution of cavity trees was similar to the distribution of a random selection of snags throughout the island (Sitka Spruce = 64%, Western Hemlock = 31%, Red Alder = 4%, Western Red Cedar = 1%). Among cavity-nesting species with five or more active nest trees, use of Sitka Spruce ranged from 57 to 79%, Western Hemlock from 13 to 40%, Red Alder from 2 to 13%, and Western Red Cedar from 1 to 6%. There was no evidence of inter-species differences in nesting tree preference (Table 2).

The nest trees of Red-breasted Sapsucker, Hairy Woodpecker, Chestnut-backed Chickadee, and Brown Creeper were significantly taller and larger in diameter than a random sample of snags on the island (Table 3); Northern Flicker nest trees were taller but not significantly larger in diameter. Nest tree height did not differ significantly among the bird species (ANOVA $F_{4,206} = 0.27$, $P = 0.93$), but diameter was significantly different among species ($F_{4,204} = 2.44$, $P = 0.04$), with Brown Creeper using trees with significantly larger diameter than Hairy Woodpecker (Tukey's pairwise: $P < 0.05$). Height and diameter were positively correlated for both the active and the randomly selected snags (active: $r^2_{166} = 0.37$, $P < 0.001$; random $r^2_{98} = 0.31$, $P < 0.01$).

Cavity-nesters used trees in decay classes 2 through 7 and showed a strong preference for decay classes 4 and 5 (Table 4, Figure 2); 50% of all active nest trees were in snags of decay class 5 and 35% were class 4. Trees in classes 4 (32%) and 5 (42%) were also the most common in the randomly selected snag sample, but the proportion of snags in decay class 2 and 3

TABLE 3. Analyses comparing mean tree heights and diameters of nest trees to a random sample of snags ($n = 100$), East Limestone Island, Haida Gwaii.

	n	Tree height (m)		Tree diameter (dbh; cm)		Effect size
		t	P	t	P	d*
Red-breasted Sapsucker (*Sphyrapicus ruber*)	126	7.0	< 0.01	7.1	< 0.01	2.94
Hairy Woodpecker (*Dryobates villosus*)	27	3.4	< 0.01	3.2	< 0.01	2.88
Northern Flicker (*Colaptes auratus*)	8	2.9	0.01	1.8	0.07	4.41
Chestnut-backed Chickadee (*Poecile rufescens*)	29	3.9	< 0.01	5.4	< 0.01	2.32
Brown Creeper (*Certhia americana*)	16	3.1	< 0.01	5.5	< 0.01	2.17

*Cohen's *d*.

TABLE 4. Decay classes of nest trees used by cavity-nesting birds and a random sample of snags on East Limestone Island, Haida Gwaii.

Species	*n*	Decay class		
		Mean	SD	Range
Red-breasted Sapsucker (*Sphyrapicus ruber*)	124	4.6	0.7	2–6
Hairy Woodpecker (*Dryobates villosus*)	26	4.8	0.9	2–6
Northern Flicker (*Colaptes auratus*)	8	5.0	0.5	4–6
Chestnut-backed Chickadee (*Poecile rufescens*)	27	4.7	0.7	3–6
Red-breasted Nuthatch (*Sitta canadensis*)	5	5.0	0.7	4–6
Brown Creeper (*Certhia americana*)	14	4.9	1.2	2–7
Northern Saw-whet Owl (*Aegolius acadicus*)	2	4.5	0.7	4–5
All cavity-bearing trees	163	4.7	0.8	2–7
Random selection of snags	100	4.5	0.9	3–7

in the random sample significantly exceeded the proportion among used trees (14% versus 3%, respectively; contingency test, $\chi^2_2 = 14.8$, $P < 0.001$). Hence, it appears that primary cavity excavators preferred trees in a more advanced state of decay than those in the random sample.

Cavity characteristics

Nest cavity heights ranged from 2.6 to 44.9 m from the base of the tree (Table 5). The Northern Flicker and Chestnut-backed Chickadee nests were, on average, the highest of the cavity-nesting species at 19.0 and 18.0 m, respectively. The lowest nests were the Northern Saw-whet Owl, but only two nests were found during the study period. For all but Brown Creeper, the mean nest height was more than 60% of the mean tree height (Table 5); Brown Creeper mean nest height of 9.0 ± 4.2 m was significantly lower than those of Red-breasted Sapsuckers, Hairy Woodpeckers, Northern Flickers, and Chestnut-backed Chickadees (Table 5).

Entrance orientation was not statistically significant for most species ($P > 0.05$; Table 6) with the exception of Red-breasted Sapsucker, for which fewer cavity openings than expected faced southeast (91°–180°; 13% of nests, $P = 0.01$); however, sample sizes for other species were much smaller.

Timing of breeding

Breeding of cavity-nesting species ranged from 21 May to 9 July (Figure 3). For Red-breasted Sapsuckers, the most common cavity-nesting species on East Limestone Island, the annual median fledging dates spanned a 16-day period from 10 June. Chestnut-backed Chickadees were usually the first to fledge, with a median date of 7 June (Table 7). Northern Flicker had the latest median fledging

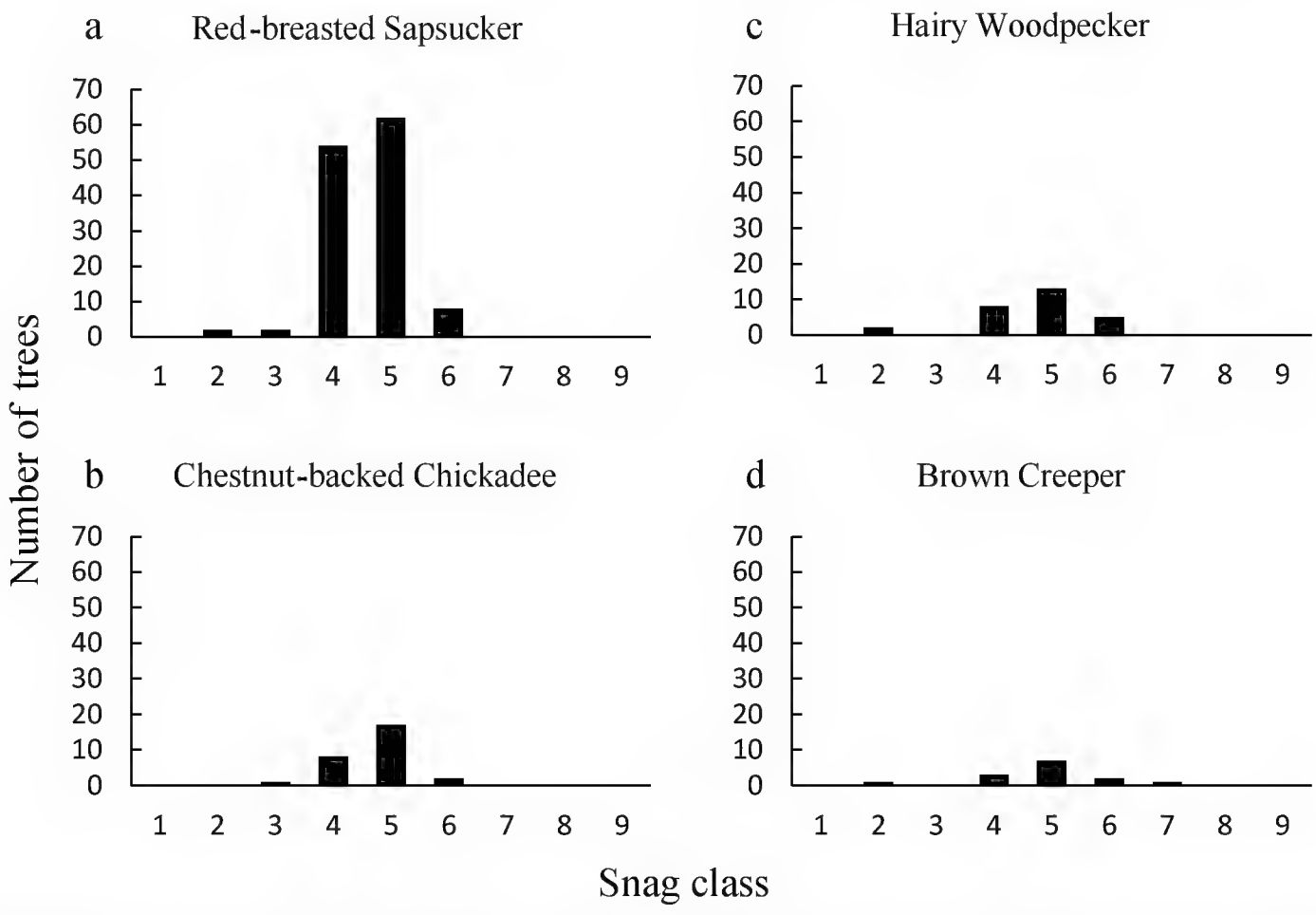

FIGURE 2. Distribution of snag classes used by different species of cavity-nesters on East Limestone Island, British Columbia, Canada (only species with $n > 10$).

TABLE 5. Nest heights of cavity-nesting species on East Limestone Islands, Haida Gwaii compared to provincial data (Campbell *et al.* 1990, 1997).

Species	*n*	Nest height (m)			% Tree height	Birds of BC
		Mean	SD	Range		Min–max (>50% range)‡
Red-breasted Sapsucker (*Sphyrapicus ruber*)	191	17.3*	7.7	3.8–44.9	76.2	1.8–24 (3–9)
Hairy Woodpecker (*Dryobates villosus*)	26	16.8*	8.2	5.4–32.8	81.2	0.9–38 (2–6)
Northern Flicker (*Colaptes auratus*)	7	19.0*	6.2	13.0–31.8	96.4	0–27 (<3)
Chestnut-backed Chickadee (*Poecile rufescens*)	26	18.0*	11.3	2.6–41.3	81.1	0–26 (2–6)
Red-breasted Nuthatch (*Sitta canadensis*)	5	13.4	0.8	12.7–14.5	62.3	0.5–20 (3–6)
Northern Saw-whet Owl (*Aegolius acadicus*)	2	9.3	0.4	9.0–9.6	73.8	2.5–13.5
Brown Creeper (*Certhia americana*)	12	9.0†	4.2	4.0–16.0	40.2	0.2–15 (2–6)

*Differs significantly from † at $P < 0.05$, Duncan Multiple Range Test.
‡Range within which greater than 50% of nests occurred.

TABLE 6. Number of cavity entrances facing northeast (NE; 1°–90°), southeast (SE; 91°–180°), southwest (SW; 181°–270°), and northwest (NW; 271°–0°) for four cavity-nesting species and *P*-values from a Rayleigh's test for uniformity for their nest cavity entrance orientation ($P < 0.05$ for a Rayleigh's test indicates clustering).

Species	NE	SE	SW	NW	*P*
Red-breasted Sapsucker (*Sphyrapicus ruber*)	70	30	55	64	0.0077
Hairy Woodpecker (*Dryobates villosus*)	6	3	4	3	0.5854
Chestnut-backed Chickadee (*Poecile rufescens*)	2	1	4	2	0.5721
Brown Creeper (*Certhia americana*)	2	3	4	1	0.7109

date of 28 June. Median dates for the start of incubation were estimated to fall between 6–9 May for the four species with the largest sample sizes (Table 7). No evidence of second broods was found for any species, but four fledging dates for Chestnut-backed Chickadees fell after 21 June, two weeks after the long-term median in early June suggesting that some chickadees either laid very late or replaced earlier failed broods.

Discussion

Tree species

On East Limestone Island, cavity-nesting species primarily used spruce and hemlock trees for nesting and these were used in proportion to the available snags on the island; very few nests were in Red Alder and only Brown Creeper was found in Western Red Cedar. This was not surprising as most alders on the island were young, small diameter trees that were not very tall or in a state of decay. In other parts of BC, deciduous trees are used by cavity-nesters, for example, Martin and Eadie (1999) and Martin *et al.* (2004) found 95% of cavities in the Cariboo-Chilcotin region of central interior BC were in Trembling Aspen (*Populus tremuloides* Michaux). The majority of these were created by Red-naped Sapsucker (*Sphyrapicus nuchalis*), Hairy Woodpecker, and Northern Flicker—a very similar primary excavator community to that on East Limestone Island.

Tree height and cavity height

Of the cavity-nesters with more than five active nest trees during the study period, the mean heights of nest trees were significantly higher than a random selection of snags, strongly suggesting that height is an important factor for the location of nest cavities on this island. In addition, all bird species except Brown Creeper created or used nest cavities in the top half of the tree. Nests were also generally much higher

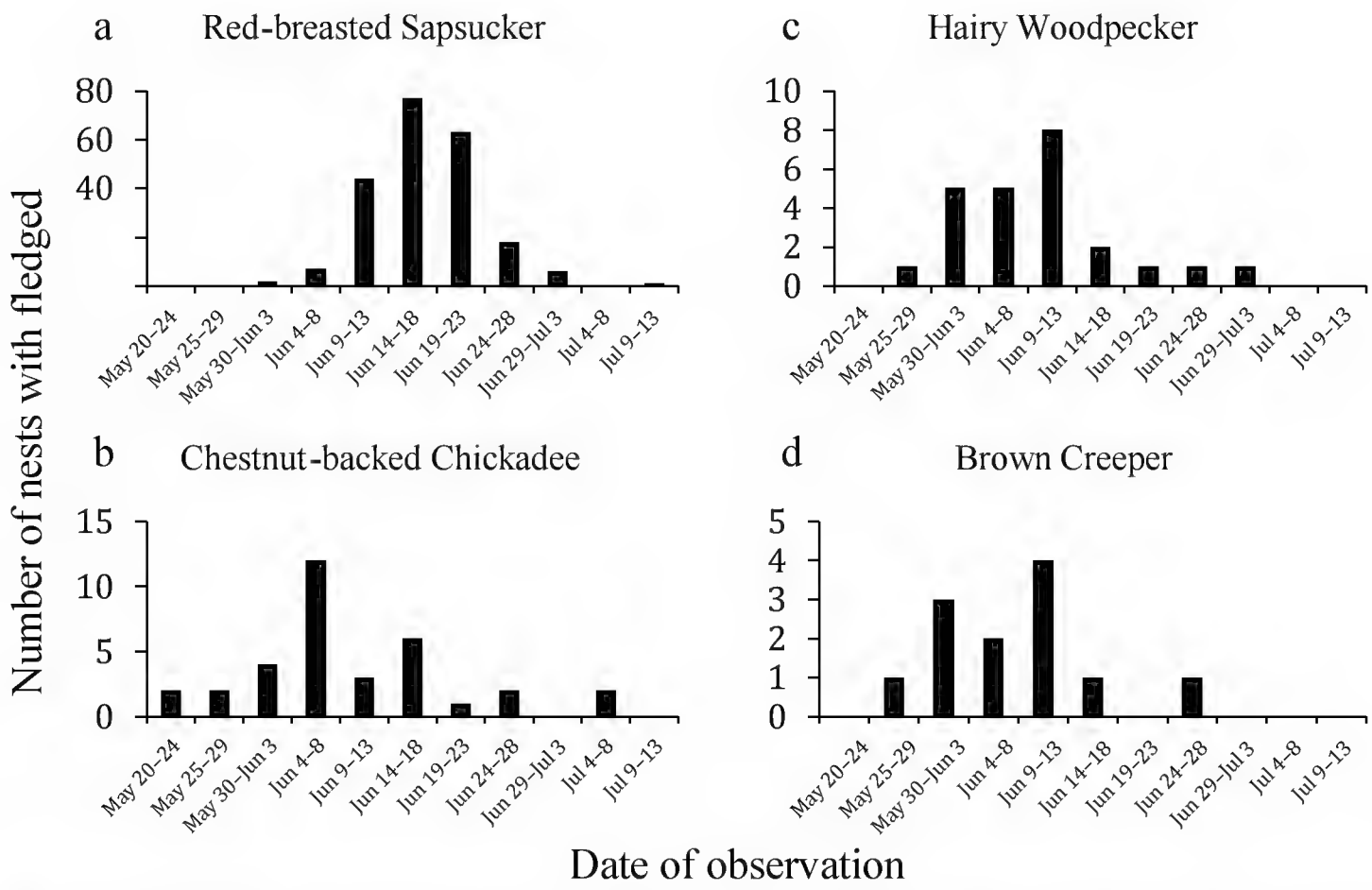

FIGURE 3. Observed fledging dates for cavity-nesting species on East Limestone Island, Haida Gwaii, British Columbia, Canada (1990–2018).

TABLE 7. Estimated median incubation and median and extreme fledging dates for cavity-nesters on East Limestone Island, Haida Gwaii, 1990–2018.

Species	*n*	Estimated median start of incubation	Median date of chick fledging	Earliest fledging date	Latest fledging date
Red-breasted Sapsucker (*Sphyrapicus ruber*)	219	7 May	17 Jun	1 Jun	13 Jul
Hairy Woodpecker (*Dryobates villosus*)	24	6 May	10 Jun	29 May	30 Jun
Northern Flicker (*Colaptes auratus*)	5	—	28 Jun	3 Jun	5 Jul
Chestnut-backed Chickadee (*Poecile rufescens*)	34	6 May	7 Jun	21 May	1 Jul
Red-breasted Nuthatch (*Sitta canadensis*)	3	—	12 Jun	31 May	16 Jun
Brown Creeper (*Certhia americana*)	10	9 May	10 Jun	28 May	28 Jun

than those reported as 'typical' (>50% of nests) by Campbell *et al.* (1990, 1997), with mean nest heights on East Limestone Island more than twice the maximum of the typical range elsewhere for all species except Red-breasted Sapsucker and Brown Creeper.

The high nest sites on East Limestone Island could be a function of predation risk, with higher nests having lower risk (Kilham 1971; Nilsson 1984). The main potential nest predator of cavity-nesting birds was Red Squirrel (*Tamiasciurus hudsonicus*), while adults might have been susceptible to predation by Red-tailed Hawk (*Buteo jamaicensis*) and Sharp-shinned Hawk (*Accipiter striatus*), both of which occur on the island. Red Squirrel was introduced to Haida Gwaii in 1950 (Golumbia *et al.* 2008) and recorded on East Limestone Island by 1983. The species is an active predator on songbird nests in the area (Martin and Joron 2003). It was the only potential predator seen entering nest cavities on East Limestone Island (A.J.G. pers. obs.). The density of squirrels on the island fluctuates significantly among years (Martin *et al.* 2008) and is high in comparison with nearby larger islands that have other mammalian predators (e.g., Pine Marten [*Martes americana*],

Black Bear [*Ursus americanus*]). One possible explanation for nest heights is that squirrels avoid tall trees denuded of leaves and branches to avoid avian predators, such as Red-tailed Hawk (visitors to East Limestone Island), or the resident Common Raven (*Corvus corax*). Furthermore, a nest near the top of a snag could result in less rainwater running into the cavity hole, compared with a cavity further down the tree (Conner 1975).

Brown Creeper nests lower than other species and build cryptic nests behind bark or rotten wood. Unlike other cavity-nesters, Brown Creeper nestlings do not call loudly from the nest when the parents are absent. Brown Creeper may depend on these cryptic habits to avoid detection and minimize predation. As a predator of small mammals and birds (Rasmussen *et al.* 2008), Northern Saw-whet Owl may be sufficiently intimidating to deter squirrels from entering their nests, which might explain why both the two owl nests found were much lower (9.0 m and 9.6 m) than the average for other species. Only three nests of the Haida Gwaii subspecies of Saw-whet Owl (*Aegolius acadicus brooksii*) had been found by 2008 (Rasmussen *et al.* 2008), one of which was on East Limestone Island. Data are too limited to know whether low nest sites are characteristic of this subspecies. However, elsewhere in BC the species uses holes at similar heights to those found on East Limestone Island (Campbell *et al.* 1990).

Tree diameter

Red-breasted Sapsucker, Hairy Woodpecker, Chestnut-backed Chickadee, and Brown Creeper all used trees with significantly greater mean dbh than that of randomly selected snags (Table 3), a finding also made by Martin *et al.* (2004) in interior BC and by Raphael and White (1984) in the Sierra Nevada. Brown Creeper selected significantly larger tree diameters than those used by Hairy Woodpecker. Height and dbh are correlated so we cannot distinguish which has the greater influence of nest site choice. While height may confer protection from predation and better drainage, greater girth may allow for deeper nests or better thermal protection (O'Connor 1978; Van Balen 1984). In addition, a larger cavity size could increase space for nestlings, reducing competition among them when being fed (Slagsvold 1989).

As a bark nesting species, Brown Creeper (Davis 1978) has different selection criteria from the other species. It tends to select trees with large sections of loose bark to nest underneath, perhaps more frequently available on larger diameter trees. The species also prefers large diameter trees for foraging (Poulin *et al.* 2008) and choosing their nest site close to their food source could be advantageous.

Decay

Trees used for cavities on East Limestone Island were mostly in an advanced state of decay, with mean decay classes ranging from 4.5–5.0 (Figure 2). These trees would have decayed heartwood with relatively hard sapwood. Such trees may be more suitable as nest trees due to the decayed heartwood being soft enough for easy excavation, with an outer shell of relatively strong sapwood surrounding and protecting the nest cavity (Kilham 1971; Conner *et al.* 1976; Miller and Miller 1980). It is worth noting that the value of differing decay states of different species of trees is not adequately represented by the BC Tree Classification System (*cf.*, Guy and Manning 1995). Trees may have a similar appearance but be harder or softer depending on their location. The location could be subject to different, perhaps stronger winds, or different climatic conditions, all of which would give the tree a different appearance, hence a different decay class.

Cavity orientation

Orientation was measured to understand nest site selection relative to microclimate. The orientation of Red-breasted Sapsucker cavity entrances was not random, perhaps because they attempt to regulate nest microclimate by orienting their nest entrances away from the prevalent southeast winds, which bring the heaviest rainfall to the island. In addition, the topography of the island allows for winds from this direction to be funneled into the interior of the island, strengthening its effect and perhaps strengthening the effect of cavity orientation. The apparent lack of preferred cavity orientation among other species may be a result of small sample size. Additional research is needed for Saw-whet Owl, as well as Northern Flicker and Red-breasted Nuthatch to shed further light on the nest site preferences of these species.

Timing of breeding

All of our nesting dates fell within the ranges indicated by Campbell *et al.* (1990, 1997) for individual species. However, Campbell *et al.* (1990, 1997) indicated a longer season (early May to end of July) for all species found on East Limestone Island. It appears that breeding on East Limestone Island varies little among species, with all initiating incubation in the first half of May, and most nesting completed by the end of June. One exception was the case of Red-breasted Sapsucker in 1999, when median fledging was six days later than in the next latest year. Breeding of open nesting species was later and less successful in 1999 because of low temperatures associated with a strong La Niña event (Gaston *et al.* 2005) and this may also have caused the late breeding of the sapsuckers.

Conclusion

This 29-year study has provided insights into the significant characteristics of nest sites created or used by cavity-nesting birds on a small island in Haida Gwaii. The results of this work suggest that a rich diversity and healthy populations of cavity-nesting species can be supported on small islands with intact mature forests. The predominance of Red-breasted Sapsucker, a primary excavator, over other hole-nesting species, suggests that suitable holes are probably abundant for secondary species, such as chickadees and nuthatches, both of which used old sapsucker holes on occasion. On the mainland, cavity nests are found in a greater variety of trees, often in live deciduous trees at much lower heights. In future, when surveys are conducted on small islands it is important that attention is paid to the upper parts of large snags to ensure that cavity nests are not overlooked. Our results support the proposal that the protection of large old snags within northwest coastal forest ecosystems is essential to providing a healthy community of cavity-nesting birds (Cockle *et al.* 2011).

Author Contributions

Writing – Conceptualization & Field Work Design: A.G., K.M., J.S.; Field Work Oversight: K.M., J.S., N.P.; Data Analysis & Original Draft: N.P. & A.G.; Writing – Review & Editing: all authors.

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APPENDIX 1. Incubation and fledging periods used in estimating dates of clutch completion for species with 10 or more records.

Species	Incubation period (days)	Fledging period (days)	Reference
Hairy Woodpecker (*Dryobates villosus*)	13	29	Jackson *et al.* 2018
Red-breasted Sapsucker *(Sphyrapicus ruber)*	14	27	Walters *et al.* 2014
Chestnut-backed Chickadee (*Poecile rufescens*)	13	20	Dahlsten *et al.* 2002
Brown Creeper (*Certhia americana*)	15	17	Poulin *et al.* 2013

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The Canadian Field-Naturalist

Rooting depth and below ground biomass in a freshwater coastal marsh invaded by European Reed (*Phragmites australis*) compared with remnant uninvaded sites at Long Point, Ontario

Calvin Lei[1], Sarah J. Yuckin[1], and Rebecca C. Rooney[1,*]

[1]Department of Biology, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1 Canada
[*]Corresponding author: rrooney@uwaterloo.ca

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Abstract

Invasive European Reed (*Phragmites australis* subsp. *australis*) outcompetes native vegetation, reducing floristic diversity and habitat value for wildlife. Research in coastal salt marshes has indicated that *P. australis* invasion may be facilitated by its relatively deep rooting depth, but in freshwater marshes the growth pattern of below ground tissues in relation to water depth is uncertain. To determine if *P. australis* is rooting more deeply than resident wetland plant species in a freshwater coastal marsh on Lake Erie, Ontario, we measured the vertical distribution of below ground biomass in *P. australis* invaded marsh sites and compared it to the below ground biomass distribution in nearby sites not yet invaded by *P. australis*. These invaded and uninvaded sites were paired by water depth, which is known to influence resource allocation and rooting depth. Below ground biomass in invaded sites was greater than in uninvaded sites ($t_{28} = 3.528$, $P = 0.001$), but rooting depth (i.e., the depth at which 90% of total below ground biomass is accounted for) was comparable ($t_{28} = 0.992$, $P = 0.330$). Using water depth and site type, general linear models could predict below ground biomass ($F_{2,55} = 9.115$, $P < 0.001$) but not rooting depth ($F_{2,55} = 1.175$, $P = 0.316$). Rooting depth is likely affected by other factors such as substrate type and the depth of the organic soil horizon.

Key words: Below ground biomass; coastal marsh; Common Reed; ecosystem effects; invasive species; Lake Erie; rhizomes; roots; wetland

Introduction

European Reed (*Phragmites australis* (Cavanilles) Trinius *ex* Steudel subsp. *australis*) is considered highly invasive in North America (Saltonstall 2002) and has profound negative effects on both coastal and inland wetlands and shores. Researchers have reported that *P. australis* replaces native vegetation (Able *et al.* 2003; Tulbure and Johnston 2010), lowers plant biodiversity (Keller 2000), and disrupts wetland integrity and ecological function (Windham and Ehrenfeld 2003; Rothman and Bouchard 2007; Tulbure and Johnston 2010; Duke *et al.* 2015). *Phragmites australis* invasion may also lead to sediment accretion, terrain flattening, and a reduction in water-filled depressions due to the accumulation of leaf litter and rhizome biomass (Able *et al.* 2003). These invasion-driven changes in wetland habitat have consequences such as the loss of toad breeding habitat (Greenberg and Green 2013), reduced abundance of at-risk birds (Robichaud and Rooney 2017), and fewer suitable nesting areas and poor microhabitats for turtle eggs (Bolton and Brooks 2010; Cook 2016). Consequently, *P. australis* was named the worst invasive plant species in Canada (Catling and Mitrow 2005, 2011).

In the Great Lakes region, *P. australis* has replaced thousands of hectares of freshwater coastal wetlands. Around Lake Erie alone, invasion estimates range from 2553 ha within the coastal wetlands (Carson *et al.* 2018) to 8233 ha within a 10 km buffer around the American portion of Lake Erie (Bourgeau-Chavez *et al.* 2013). At Long Point on Lake Erie, *P. australis* invasion is predicted to continue expanding rapidly until 2022 (Jung *et al.* 2017), and the wetland communities most commonly replaced are cattail, meadow marsh, sedge and grass hummocks, and other mixed emergent communities (Wilcox *et al.* 2003).

The invasion success of *P. australis* is due to advantageous morphological features and its ability to modify its environment. For example, *P. australis* stems can grow up to five metres tall, intercepting light and shading competitors (Hirtreiter and Potts

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2012). With its large seed heads, *P. australis* can produce hundreds of wind-dispersed seeds (Tulbure and Johnston 2010), which is an important strategy for creating new individuals (Albert *et al.* 2015). However, local expansion mainly occurs by vegetative growth (Albert *et al.* 2015), using stolon fragments and rhizomes (Mal and Narine 2004; Tulbure and Johnston 2010). Rhizomes are also important storage organs that enable *P. australis* to send up spring ramets in advance of resident species and to manage nitrogen limitation (Granéli *et al.* 1992).

Below ground, *P. australis* engineers its habitat to optimize its competitive advantage over native species (Minchinton *et al.* 2006). For example, a study on *P. australis* roots reported that hypodermal layers around roots and rhizomes protect against toxic organic compounds and anoxia (Armstrong and Armstrong 1988). Aerenchyma channels, which send atmospheric oxygen from emergent plant tissues to plant parts in anoxic soils, also allow *P. australis* to sustain deep rooting depths (Armstrong and Armstrong 1988). For example, studies from a marine coastal marsh gave estimates of *P. australis* roots growing from <1–4 m deep (Moore *et al.* 2012; Packer *et al.* 2017).

The deep rooting of *P. australis* may be an important strategy for invasion; species with deeper rooting depths are able to access nutrients and minerals lower in the soil profile compared to species with shallow rooting depths (Jobbágy and Jackson 2004). For example, in a New Hampshire study, *P. australis* had deeper rooting depths in more physically stressful environments that allowed it to access deeper, less saline groundwater and more available nutrients (Moore *et al.* 2012). Despite the competitive advantage that deep rooting may provide to *P. australis* in salt marshes (Moore *et al.* 2012), we are not aware of other studies quantifying its rooting depth in freshwater coastal marshes.

Other than the influence of salinity (Moore *et al.* 2012), variation in *P. australis* rooting depth may be due to differences in water depth, the frequency of water depth fluctuation, and substrate type, which may all influence redox conditions and oxygen availability. For example, in a greenhouse experiment, Hanslin *et al.* (2017) reported that increased amplitude of water level fluctuations resulted in increased *P. australis* rooting depths but decreased below ground biomass in the top soil regions. This finding has yet to be corroborated by studies of natural systems.

To the best of our knowledge, there are no studies in the Great Lakes region that quantify the vertical distribution and biomass of *P. australis* below ground tissues compared to resident vegetation, particularly not across a gradient in water depth. Differences in rooting depth between invasive *P. australis* and resident plant communities in these freshwater wetlands may help explain the success of *P. australis* invasion. Importantly, such differences may also have implications for the ecological effects of invasion. For example, deeper rooting could expand the penetration of oxygen into saturated wetland soils (Faußer *et al.* 2016), mobilizing carbon pools and metals that were otherwise inactive (e.g., Jacob and Otte 2003). We sought to determine if freshwater coastal marsh communities dominated by invasive *P. australis* have greater below ground biomass or deeper rooting depths compared with resident uninvaded marsh. We predicted that more below ground biomass would be produced by *P. australis* than resident plant communities because *P. australis* is so productive (Rothman and Bouchard 2007). Also, because *P. australis* has deeper rooting depths than native vegetation in marine coastal marshes (Moore *et al.* 2012), we predicted that the same trend would be true in freshwater. In addition, because water depth may affect rooting depth (Hanslin *et al.* 2017), we also tested the prediction that below ground biomass and rooting depth of *P. australis*-dominated communities would be positively correlated with water depth across a naturally occurring gradient and compared this with resident vegetation communities.

Methods

Site selection

Our study was situated at Long Point, Canada (42.581°N, 80.381°W), a sand spit that sustains over 70% of the remaining intact coastal marsh on the north shore of Lake Erie (Ball *et al.* 2003). The 40600 ha area is a designated World Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO), and an internationally important wetland under the Ramsar Convention (Ministry of Natural Resources and Forestry 2017). This ecologically important region is threatened by continuing expansion of high-density *P. australis* (Jung *et al.* 2017).

Sample sites within Long Point were established across a range of water depths at which *P. australis* invasion is common (13.7–55.7 cm), with sites dominated by high density *P. australis* monocultures paired by water depth with sites either dominated by cattails (*Typha* spp.; >30 cm water depth) or by meadow taxa, including graminoids, sedges, and forbs (<40 cm water depth). Sites in the 30–40 cm depth range were either meadow marsh or *Typha* spp. marsh, as the two communities stratify by depth and rarely mix. Sites were dispersed across the Crown

Marsh and Long Point Provincial Park management units, spaced between 100 and 2000 m apart. This area is representative of wet meadow and emergent lacustrine marsh in Lake Erie, with substrate ranging from organic in shallower depths to pure sand in deeper locations.

Core collection

Fieldwork was conducted in May 2017. Using a 2.54 cm diameter soil gouge auger, soil cores (0.3–0.75 m deep) were sampled from sites invaded by *P. australis* and paired uninvaded marsh sites. It was not possible to obtain cores of uniform length due to differences in the thickness of the organic horizon and difficulties penetrating the underlying sand substrate. In total 29 pairs of cores were collected. The cores were then sub-sectioned into 10 cm long segments and frozen until they could be processed. For comparison, Moore *et al.* (2012) who also examined belowground biomass trends in marsh invaded by European *P. australis*, collected 100 cm long cores from 10 tidal marshes along New Hampshire's Atlantic coast using the same diameter gouge auger and sub-sectioned them into 5 cm long segments.

Core processing

Core segments were thawed for about 24 h and then washed over two nested sieves: a coarser (1.7 mm) sieve over a finer (425 µm) sieve. All live rhizomes and all root tissues were retrieved and dried at 80°C to a constant weight (minimum 48 h). Dead roots may have been included in our weights as we did not find it possible to reliably differentiate live and dead roots. The dried below ground tissues were then weighed on a Mettler Toledo analytical balance (MS204S, Columbus, Ohio, USA) with a 0.0001 g accuracy. For comparison, Moore *et al.* (2012) picked live roots and rhizomes from trays partially filled with water and then oven dried to a constant weight at 65°C for a minimum of 48 h.

Data analysis

For the purposes of this study, rooting depth was defined as the depth (cm) at which 90% of the cumulative below ground biomass was accounted for. Below ground biomass was defined as the total root and rhizome mass per unit area (g/m^2), recognizing that the core depths varied with the thickness of the organic horizon. To test whether below ground biomass was greater in *P. australis* invaded sites compared to uninvaded sites, we used a paired-samples, one-tailed *t*-test. To test whether rooting depth was greater in *P. australis* invaded sites than uninvaded sites, we used another paired-samples, one-tailed *t*-test. Lastly, to test whether water depth is a significant predictor of below ground biomass and rooting depth, we used general linear models (GLM) with a least squares estimation framework to model variation in below ground biomass and rooting depth based on water depth, site type (*P. australis* invaded or uninvaded), and their interaction. Models are thus represented by the general form:

$$y = \beta_1 W + \beta_2 T + \beta_3 T \times W + \beta_0 + \varepsilon,$$

where W is water depth, T is site type, and ε is error. If the interaction terms were not significant, the model would be re-run to only include the main factors: water depth and site type. In all cases, we used an alpha value of 0.05 and Type III sums of squares. Analyses were completed using IBM SPSS Statistics 20.

Results

Paired-samples t*-tests for below ground biomass and rooting depth*

Phragmites australis invaded marsh had greater below ground biomass than uninvaded marsh habitat, when meadow and *Typha* spp. marsh are considered jointly (paired-samples *t*-test, $t_{28} = 3.528$, $P = 0.001$; Figure 1a). Although the difference between *Typha* spp. dominated cattail marsh and *P. australis* invaded marsh is negligible, it revealed that the difference is primarily between *P. australis* invaded and meadow marsh sites (Figure 1a).

There is no significant difference in rooting depth between *P. australis* invaded marsh and uninvaded marsh (paired-samples *t*-test, $t_{28} = 0.992$, $P = 0.330$; Figure 1b). This appears evident in both meadow marsh and cattail marsh components of the uninvaded sites (Figure 1b).

The down-core distribution of below ground biomass suggests that core depths were sufficient to capture the bulk of total below ground tissues (Figure 2). This was true for invaded (Figure 2a) and uninvaded (Figure 2b) sites, across a range of water depth intervals between 13.7 and 55.7 cm. Below ground biomass was detected to a maximum of 80 cm soil depth yet peaked within the top 30 cm of the soil profile, regardless of site type (Figure 2).

General linear models for below ground biomass and rooting depth

For below ground biomass, the interaction term was not significant (Table S1a, Figure S1), so we removed it and re-ran the GLM as

$$\textit{below ground biomass} = \beta_1 W + \beta_2 T + \beta_0 + \varepsilon.$$

This model provided a reasonable fit (adjusted $r^2 = 0.222$; GLM, $F_{2,55} = 9.115$, $P < 0.001$; details in Table S1b). Likewise, for rooting depth, the interaction term was not significant (Table S2a), so we removed it and re-ran the GLM as

$$\textit{rooting depth} = \beta_1 W + \beta_2 T + \beta_0 + \varepsilon.$$

However, this model proved to be a poor predictor

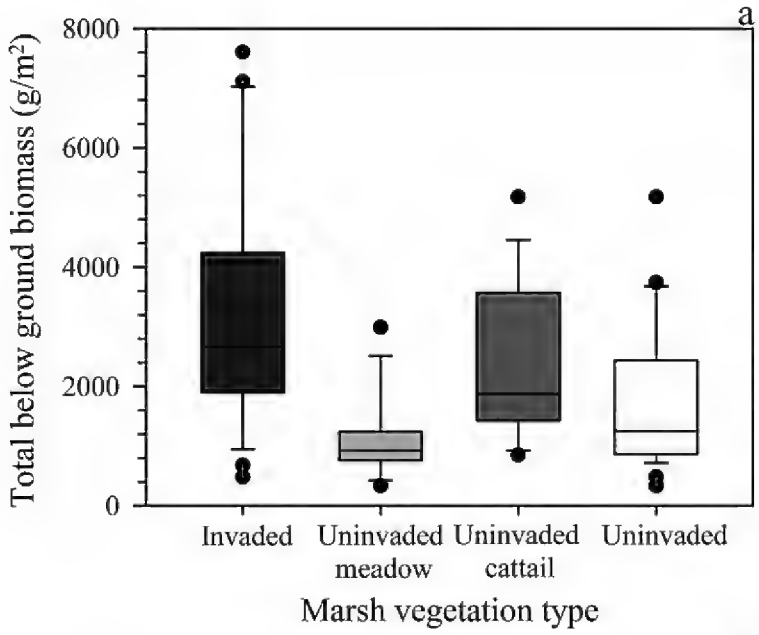

FIGURE 1. Total below ground biomass and rooting depth in European Reed (*Phragmites australis*) invaded and uninvaded marsh. Boxplots depicting a. total below ground biomass (g/m^2) and b. rooting depth (cm), contrasting *P. australis* invaded marsh (dark grey; $n = 29$) and uninvaded marsh (white; $n = 29$) sites. Note that uninvaded marsh is divided into shallower depth meadow marsh (light grey; $n = 15$) and deeper water cattail (*Typha* sp.) marsh (grey; $n = 14$) communities.

of rooting depth (adjusted $r^2 = 0.006$; GLM, $F_{2,55} = 1.175$, $P = 0.316$; details in Table S2b).

Discussion

Our research objectives were to determine if *P. australis* invaded marsh produced more below ground biomass, and deeper rooting depths than uninvaded marsh in a freshwater coastal marsh, as has been observed in marine coastal marshes (e.g., Ravit *et al.* 2006; Moore *et al.* 2012). Controlling for water depth, we observed that *P. australis* invaded marsh had more below ground biomass than uninvaded marsh, however, rooting depths did not differ significantly between *P. australis* invaded and uninvaded marsh sites. Like site type, water depth was a significant predictor of below ground biomass (g/m^2) but not of rooting depth. Interestingly, although the largest difference in below ground biomass was evident between *P. australis* invaded sites and meadow marsh sites, which were restricted to shallower water depths, we detected no significant interaction between water depth and site type when predicting either below ground biomass or rooting depth.

Greater below ground biomass may provide *P. australis* a competitive advantage allowing it to usurp soil resources (van Wijk *et al.* 2003) and facilitate dispersion by vegetative reproduction (Saltonstall 2002; Tulbure and Johnston 2010; Albert *et al.* 2015). The current literature reports below ground biomass values for *P. australis* in the range of 886 g/m^2 (Rothman and Bouchard 2007) to 1368 g/m^2 (Windham 2001); for cattail marsh in the range of 742 g/m^2 (Rothman and Bouchard 2007) to 2461 g/m^2 (Ouellet-Plamondon *et al.* 2004); and for meadow species, such as Saltmeadow Cordgrass (*Sporobolus pumilus* (Roth) P.M. Peterson & Saarela) and Bluejoint Reedgrass (*Calamagrostis canadensis* (Michaux) Palisot de Beauvois), in the range of 256 g/m^2 (Ouellet-Plamondon *et al.* 2004) to 757 g/m^2 (Windham 2001). Our measures of below ground biomass show the same pattern in relative magnitude among the three communities but are noticeably higher than other published values: averaging 3137 g/m^2 for *P. australis*, 2372 g/m^2 for cattail marsh, and 1146 g/m^2 for meadow marsh. Our measurements may be high due to particularly dense growth, favourable edaphic conditions in intact freshwater coastal marsh, or because we were unable to differentiate live tissues from recently dead tissues.

When uninvaded marsh was separated into cattail and meadow marsh communities, we noted higher average below ground biomass in uninvaded cattail marsh, clearly overlapping with the below ground biomass typical of *P. australis*. This indicates that the effects of invasion on below ground biomass is likely more evident where *P. australis* replaces meadow marsh than where it invades cattail marsh. Yet, despite this difference in mean below ground biomass between cattail and meadow marsh, we fit a single slope relating the below ground biomass of uninvaded sites to water depth collectively. Future research should explicitly test for the role of resident vegetation community type on limiting the magnitude of *P. australis* invasion effects on invaded ecosystems.

Importantly, though invasion by *P. australis* in freshwater coastal marsh may increase overall below ground biomass, the concern that *P. australis* below ground tissues might penetrate more deeply than resident species and thus alter nutrient and metal fluxes in freshwater marshes is unfounded. Contrary to previous studies (e.g., Ravit *et al.* 2006; Moore *et al.* 2012), we observed no difference in rooting depth

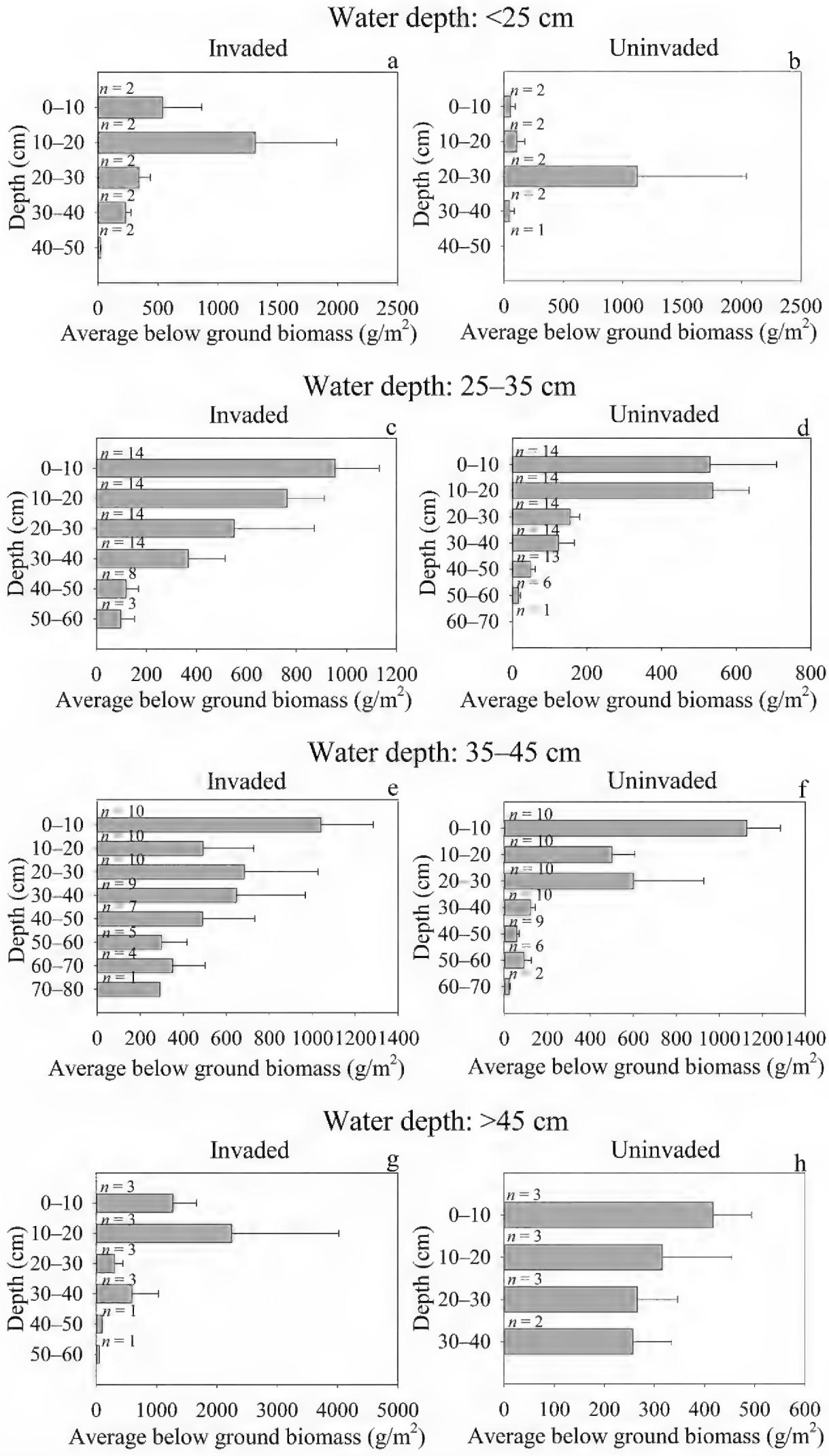

FIGURE 2. Down-core distribution of below ground biomass at different water depths. Down-core distribution of below ground biomass, contrasting European Reed (*Phragmites australis*) invaded sites (a, c, e, g) and uninvaded sites (b, d, f, h) at different water depth intervals: <25 cm (a, b), between 25–35 cm (c, d), between 35–45 cm (e, f), and >45 cm (g, h). The *n* above each bar indicates the number of cores in which living below ground tissues were detected at the indicated water and soil depth, in the indicated site type. Error bars are SE.

among the invaded and uninvaded sites. Moore *et al.* (2012) surmised that in marine coastal marsh, *P. australis* may produce deeper roots to access freshwater pockets. If this were so, it might explain why *P. australis* was not rooting more deeply than resident species in our freshwater coastal marsh. Alternatively, these published studies may differ from ours in the frequency and amplitude of water depth fluctuations that can also influence rooting depth (Hanslin *et al.* 2017). Another important factor is likely the wetland soil type and stratigraphy. Moore *et al.* (2012) reported that sandy mineral soils may inhibit deep penetration of roots. Long Point has a sand mineral soil beneath an organic horizon of variable thickness; the sand soil may have limited rooting depth for all species in our study.

Because *P. australis* produces significantly more below ground biomass in the same depth of rhizosphere as resident vegetation communities, we expect that root processes such as enhanced gas diffusion in the rhizosphere, oxidation of waterlogged anoxic soils (Armstrong and Armstrong 1988; Bart and Hartmann 2000), and the release of allelochemicals (Rudrappa *et al.* 2007) provide *P. australis* a competitive advantage and contribute to its invasion success. Yet clearly, given the equivalent rooting depths of *P. australis* invaded and uninvaded marsh, these communities experience a common rooting depth limit. This conclusion is further supported by our observation that meadow marsh, despite producing less below ground biomass than cattail marsh, nonetheless roots at an equivalent depth

Conclusion

Below ground biomass in *P. australis* invaded marsh significantly exceeded that in resident communities of meadow marsh and cattail marsh, after accounting for water depth, but rooting depths were equivalent. Consequently, root densities must be greater in *P. australis* invaded marsh, potentially contributing to its invasion success in Long Point. Because *P. australis* did not root more deeply than resident vegetation in our freshwater coastal marsh study system, concerns around invasion mobilizing deep pools of otherwise inactive carbon or metals may be generally unwarranted. The novel quantitative data presented in this study increases our understanding of *P. australis* invasion in freshwater lacustrine coastal marsh habitat and establishes the hypothesis of common limits to rooting depth in invaded and uninvaded sites that should be tested in other study systems.

Author Contributions

Conception & Design: R.C.R., S.J.Y., and C.L.; Field Work: S.J.Y.; Lab Work: C.L. and S.J.Y.; Data Analysis & Interpretation: R.C.R., S.J.Y., and C.L.; Writing – First Draft: C.L.; Writing – Review & Editing: R.C.R., S.J.Y., and C.L.; Funding Acquisition: R.C.R.

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SUPPLEMENTARY MATERIAL:

FIGURE S1. Total below ground biomass with water depth for European Reed (*Phragmites australis*) invaded sites (solid line and black triangles; $n = 29$) and uninvaded sites (dashed line and white circles; $n = 29$).

TABLE S1. Results table for GLM predicting total below ground biomass with and without interaction term.

TABLE S2. Results table for GLM predicting rooting depth with and without interaction term.

The Canadian Field-Naturalist

Flathead Catfish (*Pylodictis olivaris*) reproduction in Canada

Colin Illes[1,*], Julia E. Colm[1], Nicholas E. Mandrak[2], and David M. Marson[1]

[1]Asian Carp Program, Fisheries and Oceans Canada, 867 Lakeshore Road, Burlington, Ontario L7S 1A1 Canada
[2]Department of Biological Sciences, University of Toronto Scarborough, 1265 Military Trail, Toronto, Ontario M1C 1A4 Canada
[*]Corresponding author: colin.illes@dfo-mpo.gc.ca

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Abstract

Eleven Flathead Catfish (*Pylodictis olivaris*), representing at least five age classes, were collected between 2016 and 2018 in the lower Thames River, Ontario, Canada. The capture of two juveniles (total lengths 78 mm and 82 mm), the first records of juveniles in Canada, is a strong indication that reproduction has occurred. Previous records were thought to be individuals that dispersed from known populations in American waters of Lake Erie. Flathead Catfish is currently designated as data deficient by the Committee on the Status of Endangered Wildlife in Canada. These new findings may provide sufficient data to reconsider the conservation status of this species.

Key words: Flathead Catfish; *Pylodictis olivaris*; reproduction; Great Lakes; Lake St. Clair; Thames River; juvenile; young-of-year

Introduction

Flathead Catfish (*Pylodictis olivaris*) is found throughout the Mississippi River basin and lower Laurentian Great Lakes (Page and Burr 2011); however, it is uncertain whether the species is native to the Great Lakes basin (Fuller and Whelan 2018). It is a benthic fish species preferring turbid (Lee and Terrell 1987; Hesse 1994), warm water (Becker 1983) in low-gradient, moderate to large rivers (Lee and Terrell 1987), and is commonly associated with woody debris, undercut banks, and substrate depressions throughout its range (Becker 1983; Hesse 1994; Grussing *et al*. 1999; Jackson 1999; Daugherty and Sutton 2005a). Flathead Catfish reach sexual maturity between three and six years of age when fish are 375–539 mm in total length (TL; Minckley and Deacon 1959; Perry and Carver 1977). Reproduction occurs in June and July when water temperatures reach at least 22.2°C (Becker 1983). Flathead Catfish use depressions and natural cavities to construct nests (Cooper 1983; Cross 1967) and females lay up to 31 579 eggs (Becker 1983). A detailed description of the life history of Flathead Catfish was reported by Goodchild (1993).

Flathead Catfish is taxonomically and morphologically different from all other catfish species in the Great Lakes basin. Differences include its protruding lower jaw, ventrally compressed head, large adipose fin, and backward extensions of the premaxillary tooth patches (although Stonecat [*Noturus flavus*] shares the latter characteristic). Flathead Catfish has a varying amount of mottled pigmentation on the body, and the upper lobe of the caudal fin has a pale tip (Figure 1), although these traits can be absent or less obvious in larger fish. Flathead Catfish has a slightly forked caudal fin in contrast to the deeply forked caudal fin of Channel Catfish (*Ictalurus punctatus*).

Flathead Catfish has a short anal fin with a ray count of 13–18 (Trautman 1981), which differentiates it from Channel Catfish (25–28), Yellow Bullhead (*Ameiurus natalis*, 24–27), Brown Bullhead (*Ameiurus nebulosus*, 20–23) and, in some cases, Black Bullhead (*Ameiurus melas*, 17–21; Scott and Crossman 1998); all anal ray counts include rudimentary rays. Furthermore, Flathead Catfish has serrations on both edges of its pectoral spines whereas Channel Catfish and Brown and Black Bullheads have serrations only on the posterior edge. Madtoms (*Noturus* spp.) could be confused with juvenile Flathead Catfish, but are distinguished by a connected adipose fin and caudal fin, which are separate in Flathead Catfish.

In the Great Lakes, Flathead Catfish has been recorded in the Lake Erie, Lake St. Clair, Lake Huron, Lake Michigan, and Lake Superior basins. Since 1890, when Flathead Catfish was first recorded in Lake Erie, it has been documented in seven tribu-

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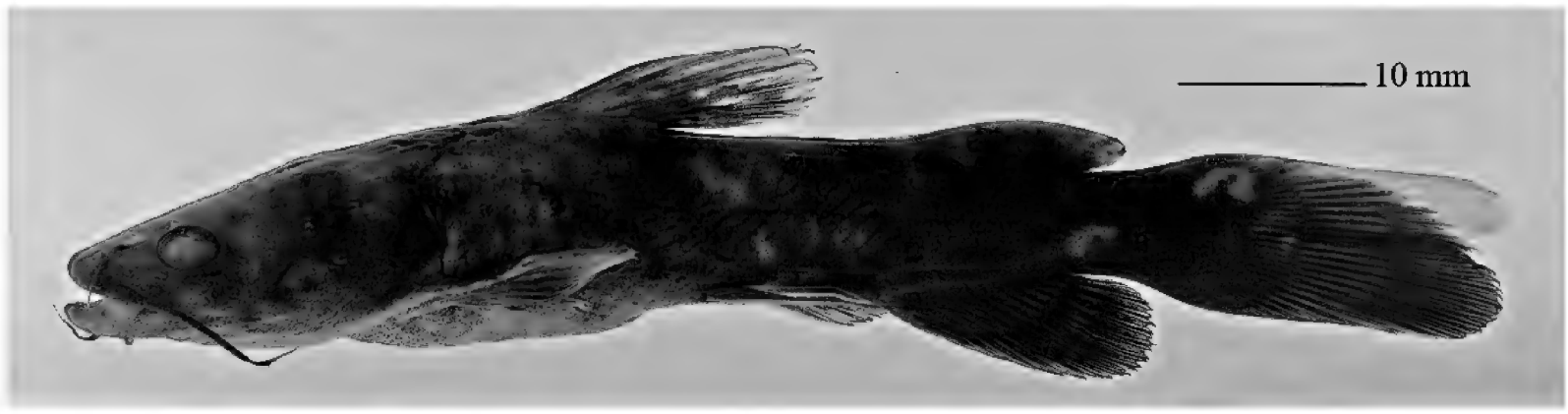

FIGURE 1. Juvenile Flathead Catfish (*Pylodictis olivaris*), 78 mm total length, captured on 31 August 2016 in the lower Thames River, Ontario, Canada. Photo: Colin Illes.

taries and is believed to have spread to the Lake St. Clair (Goodchild 1993; COSEWIC 2008) and Lake Huron basins where it has been recorded in six tributaries since the first records in 1989 and 1991, respectively (Fuller and Whelan 2018). In Lake Michigan, Flathead Catfish was first recorded in 1922 and has since been documented in 11 tributaries (Fuller and Whelan 2018). In addition, there is a single record of a Flathead Catfish in the Lake Superior basin, captured in a pond in the Au Train River watershed and believed to be an unauthorized release (Fuller and Whelan 2018). A detailed description of the historical and current distribution of Flathead Catfish in the American Great Lakes basin is provided by Fuller and Whelan (2018).

Whether Flathead Catfish is native to the Great Lakes basin is not known because of poorly documented historical records. Historical publications variously mention (e.g., Trautman 1957) and do not mention (e.g., Evermann 1902) the presence of Flathead Catfish in the lower Great Lakes. Based on a review of the literature and capture data, Fuller and Whelan (2018) concluded that Flathead Catfish is not native to the Great Lakes basin, with the possible exception of a small population documented since 1890 in the Huron River, Lake Erie (Trautman 1957). Conversely, Roth *et al.* (2012) indicated that Flathead Catfish is native to the Erie and Michigan basins.

The origin of several other fishes in the Great Lakes basin is also unclear. Much like Flathead Catfish, Gizzard Shad (*Dorosoma cepedianum*), and Bigmouth Buffalo (*Ictiobus cyprinellus*) have uncertain origins in Lake Erie and may have spread from the Mississippi River basin into Lake Erie where populations have continually expanded because of warming temperatures (Miller 1957; Goodchild 1993). These fishes are considered native to the Great Lakes basin (e.g., Lee *et al.* 1980; Trautman 1981; Scott and Crossman 1998; Roth *et al.* 2012), despite a lack of historical records and vouchered specimens. This has been attributed to misidentification with other species (e.g., Alewife [*Alosa pseudoharengus*], Smallmouth Buffalo [*Ictiobus bubalus*]), and confusion with early introductions of Bigmouth Buffalo (Miller 1957; Trautman 1981). Gizzard Shad and Bigmouth Buffalo were first recorded in Lake Erie in 1848 and 1878, respectively (Miller 1957; Trautman 1981). Roth *et al.* (2012) identified only three species of questionable native status in the Great Lakes basin: Ghost Shiner (*Notropis buchanani*), questionably native to the Erie and Huron basins; and Brindled Madtom (*Noturus miurus*) and Orangethroat Darter (*Etheostoma spectabile*) to the Michigan basin.

In Canada, Flathead Catfish has been collected only in the Great Lakes basin with records limited to the western basin of Lake Erie and Lake St. Clair (COSEWIC 2008). The first Canadian capture of a Flathead Catfish was in Lake Erie, in 1978; it was caught west of Point Pelee, 3.2 km north of the tip, in a commercial trap net (Crossman and Leach 1979). Subsequently, three additional single specimens were captured in the Point Pelee area in 1986, 2005, and 2011 (COSEWIC 2008; Ontario Ministry of Natural Resources and Forestry [OMNRF] unpubl. data). All three fish were recorded in commercial trap nets west of Point Pelee and south of Sturgeon Creek within 8 km of each other. In 1989, Flathead Catfish was first captured by commercial long line in Lake St. Clair, 3.2 km from the mouth of the Thames River (Royal Ontario Museum unpubl. data). In 2001 and 2003, two additional Flathead Catfish were captured in Lake St. Clair in the St. Luke's Bay area, 10 km north of the Thames River mouth (Figure 2), both in a commercial trap net (OMNRF unpubl. data). Based on the four known single specimens captured in Canadian waters between 1978 and 2001, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) could not determine whether Flathead Catfish was native to Canada or a vagrant and, thus, assessed it as data deficient (COSEWIC 2008).

Because of its preference for hard-to-sample habitats (e.g., beneath woody debris and structured substrate in deep water), low population abundance, and solitary behaviour, Flathead Catfish has been notori-

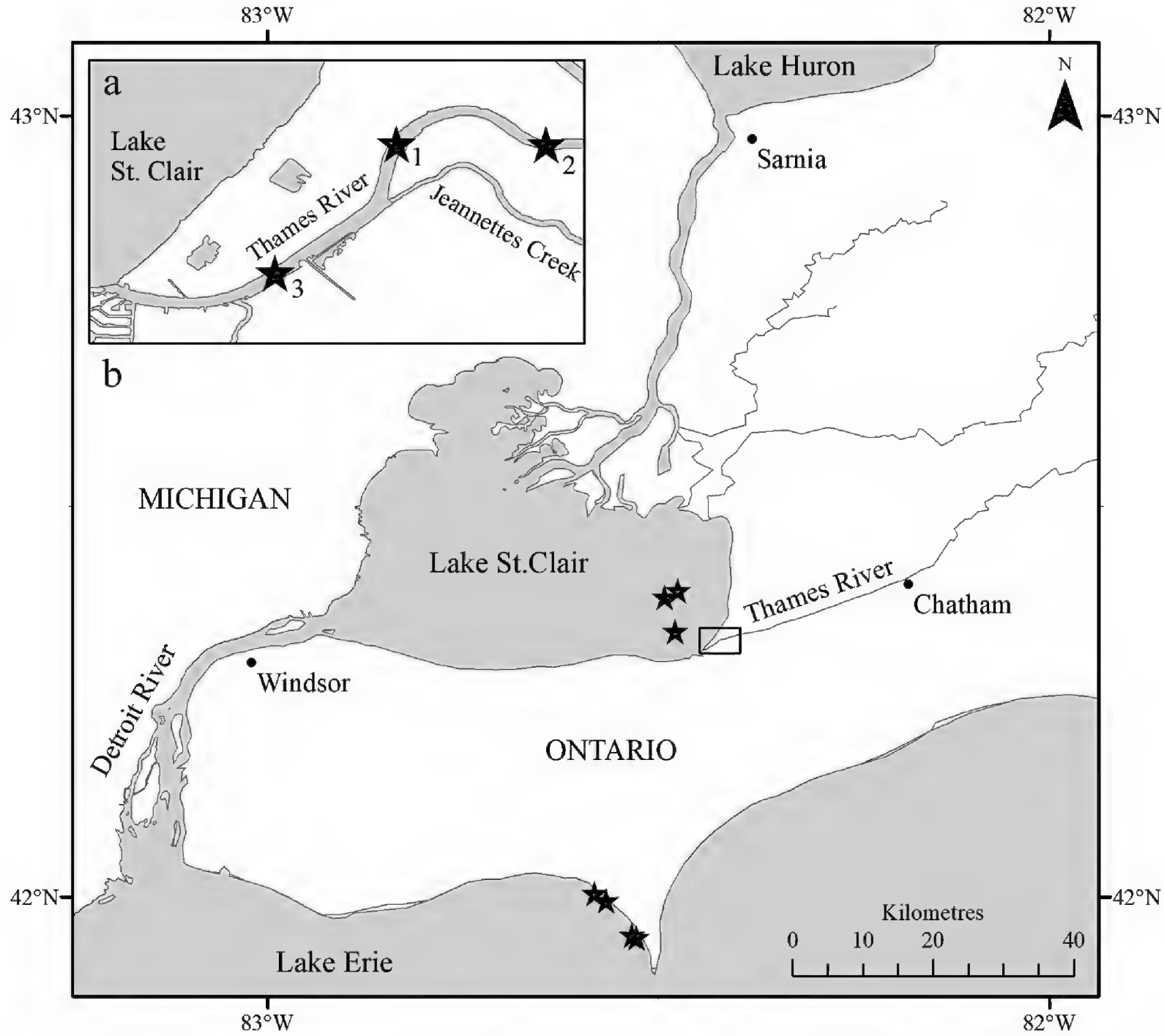

FIGURE 2. Capture locations of Flathead Catfish (*Pylodictis olivaris*) in Canadian waters of the Great Lakes basin, a. 2016–2018 and b. 1979–2018. Source: Unpublished data from Fisheries and Oceans Canada, the Ontario Ministry of Natural Resources and Forestry, and the Royal Ontario Museum, sourced under the Open Government Licence Ontario.

ously difficult to assess in river systems (Stauffer *et al.* 1996; Vokoun and Rabeni 1999). This has led to limited targetted sampling and knowledge about the species, especially in the Great Lakes (Daughtery and Sutton 2005a). To our knowledge, there has been only one population estimate for Flathead Catfish in the Great Lakes basin, conducted in the lower St. Joseph River, Michigan, which estimated an abundance of 5453 individuals (Daughtery and Sutton 2005b).

In this study, we report recent records of Flathead Catfish that indicate reproduction in the Canadian waters of the Great Lakes basin and discuss implications of these records for future management.

Methods

The Thames River, a tributary of Lake St. Clair, is a large, turbid river with a high diversity of fish and mussel species, 25 of which are at risk (Cudmore *et al.* 2004). The Thames River watershed has been impacted by agriculture and urban and rural development (Cudmore *et al.* 2004). In addition to supporting several imperilled species, the river is highly suitable for the reproduction of four species of invasive Asian carp (Cudmore *et al.* 2017) and, therefore, is sampled routinely by Fisheries and Oceans Canada's Asian Carp Program (Colm *et al.* 2019a).

This sampling occurred between May and November, 2013–2018, using seven gear types to target adult and juvenile Asian carp, while also collecting baseline fish community data (Marson *et al.* 2014, 2016, 2018; Colm *et al.* 2018, 2019a,b). Sampling effort in the lower Thames River during this period is summarized in Table 1.

Flathead Catfish were captured in the lower Thames River using three gear types: boat electrofishing (n =

TABLE 1. Summary of sampling effort in the lower Thames River, 2013–2018, as part of the early detection surveillance efforts of Fisheries and Oceans Canada's Asian Carp Program.

Year	Boat electrofishing		Hoop net		Mini-fyke net		Seine net		Trap net		Trammel net	
	No. sites	Effort, h	No. sites	Effort, h	No. sites	Effort, h	No. sites	Effort, hauls	No. sites	Effort, h	No. sites	Effort, h
2013	4	0.4	0	0.0	0	0.0	2	6	0	0.0	2	1.8
2014	19	3.1	3	112.4	0	0.0	0	0	4	91.4	5	1.8
2015	33	5.6	7	311.1	0	0.0	0	0	12	244.4	13	9.1
2016	25	4.6	0	0.0	6	130.4	0	0	7	153.6	8	5.4
2017	22	3.8	10	460.1	7	155.9	0	0	10	214.4	9	2.3
2018	28	6.0	9	397.4	16	355.1	2	5	13	293.8	14	12.4

Sources: Marson *et al.* 2014, 2016, 2018; Colm *et al.* 2018, 2019a,b.

4), hoop nets ($n = 2$), and trammel nets ($n = 5$). Before 2018, the boat electrofisher was dual-boom, 6.4 m in length, and fitted with a 7.5 Generator Powered Pulsator (Smith-Root, Vancouver, Washington, USA). In 2018, the boat electrofisher used in sampling was 7.3 m in length, dual-boom, and fitted with an Infinity Box (Midwest Lake Electrofishing, Polo, Missouri, USA). Two sizes of hoop nets were used: 1.5 m in diameter, 6.1 m in length, with 2.5-cm square mesh; and 0.91 m in diameter, 4.57 m in length, with 2.5-cm square mesh. Trammel nets were 183 m in length, 4.3 m in height, with 10.1-cm bar mesh and 45.7-cm outer wall panels. Trammel nets were often used in combination with boat electrofishing as this is an effective method for targetting Grass Carp (*Ctenopharyngodon idella*), a species of Asian carp, in the Great Lakes basin (D.M.M. pers. obs.); however, fishes captured with the two gear types were processed separately. All gear types and the scope of sampling (including other locations in the Great Lakes basin) are described in Colm *et al.* (2019a).

Results

During 2016–2018, 11 Flathead Catfish (Table 2) were captured in three locations in the lower Thames River, near the mouth of Jeannettes Creek, Kent County, Tilbury Township (42.329°N, 82.421°W) (Figure 2a). No Flathead Catfish were detected in 2013–2015, despite sampling in similar areas to 2016–2018. In August 2016, we recorded three Flathead Catfish, with TL 78–566 mm, at two locations. All three fish were captured using a boat electrofisher near shore in close proximity to woody debris on a clay–silt substrate (Table 2). The first location had an undercut bank with a single cluster of woody debris; the second had abundant large woody debris, including trees, logs, and branches, and a water depth of ~1 m at the bank. In June 2017, a Flathead Catfish measuring 365 mm TL was captured with a hoop net in a new location with abundant submerged logs and branches. This individual was caught farthest downstream, 1.3 km from the Thames River mouth. In September 2017, two Flathead Catfish measuring 833 mm and 815 mm TL were captured using a

TABLE 2. Capture data for Flathead Catfish (*Pylodictis olivaris*). Capture locations shown in Figure 2a.

Date	Total length, mm	Temp., °C	Turbidity, NTU	Max. site depth, m	Substrate	Coarse woody debris, Y/N	Gear type	Location of capture	ROM catalogue no.
30 Aug. 2016	566	26.29	28.77	4.2	Clay–silt	Y	Boat electrofishing	1	101500
30 Aug. 2016	82	27.17	27.44	2.0	Clay–silt	Y	Boat electrofishing	2	105705
31 Aug. 2016	78	26.67	25.77	2.1	Clay–silt	Y	Boat electrofishing	2	101375
20 June 2017	365	24.61	16.04	2.8	Clay–silt	Y	Hoop net	3	109946
13 Sept. 2017	833	20.34	23.70	4.1	Clay–silt	Y	Trammel net	1	NA
14 Sept. 2017	815	21.44	11.30	2.0	Clay–silt	Y	Boat electrofishing	2	NA
26 June 2018	820	23.71	23.11	5.0	Clay–silt	Y	Hoop net	2	NA
27 Sept. 2018	697	20.31	31.17	4.0	Silt–clay	Y	Trammel net with boat electrofishing	2	NA
27 Sept. 2018	765	20.22	20.86	3.8	Silt–clay	Y	Trammel net with boat electrofishing	1	NA
27 Sept. 2018	743	20.22	20.86	3.8	Silt–clay	Y	Trammel net with boat electrofishing	1	NA
2 Oct. 2018	388	18.29	25.13	4.0	Clay–silt	Y	Trammel net with boat electrofishing	3	NA

Source: Fisheries and Oceans Canada unpubl. data.
Note: NTU = nephelometric turbidity units, ROM = Royal Ontario Museum.

trammel net and boat electrofisher (Table 2). The 815-mm individual was the farthest upstream record, 6.3 km from the Thames River mouth. In 2018, five additional Flathead Catfish were collected, measuring 388–820 mm TL. The 820-mm individual was captured using a hoop net at the deepest recorded capture of 5 m. The other four Flathead Catfish were captured in trammel nets used in combination with boat electrofishing (Table 2).

Four specimens of Flathead Catfish captured in 2016 and early 2017 were preserved in 10% buffered formalin, stored in 70% ethanol, and catalogued at the Royal Ontario Museum (Table 2). Digital voucher photos were taken of the remaining seven fish before they were released.

Using length-at-age data from the literature (Mayhew 1969; Young and Marsh 1990; Kwak *et al.* 2006; Sakaris *et al.* 2006), we estimate that the 11 Flathead Catfish were from five different age classes (Figure 3).

Discussion

We report the first indication of Flathead Catfish reproduction in the Canadian waters of the Great Lakes basin. Over six consecutive years of sampling, 11 individuals were detected in the lower Thames River, Ontario. To our knowledge, no length-at-age data are available for Flathead Catfish in the Great Lakes basin. Flathead Catfish collected on 30 August 2016 and 31 August 2016 with TLs of 78 mm and 82 mm, respectively, are assumed to be young-of-year. In addition to being the first recorded juveniles in Canada, these are the first records of Flathead Catfish from a river system in Canada; previous detections were in large bays.

In the first year of growth, Flathead Catfish has been documented to reach 100 mm TL in Ohio (Trautman 1981) and 145 mm TL in Arizona (Young and Marsh 1990). Daugherty and Sutton (2005b) recorded Flathead Catfish measuring 87 mm and 93 mm TL, which were assumed to be young-of-year, while sampling the lower St. Joseph River, Michigan, June through September 2002–2003.

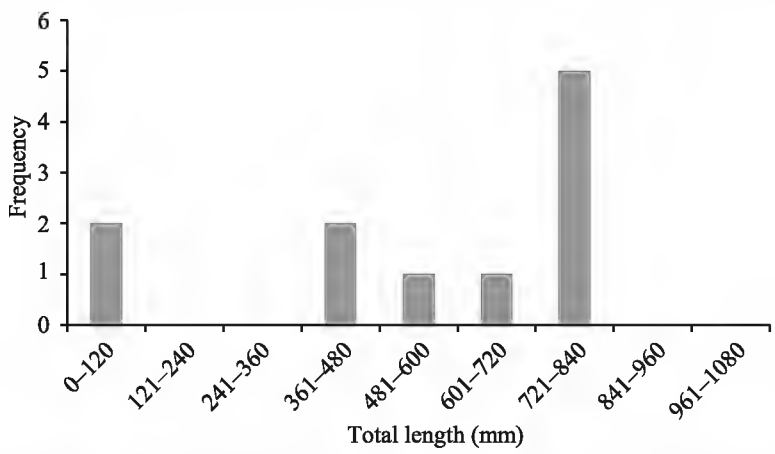

FIGURE 3. Length–frequency distribution of Flathead Catfish (*Pylodictis olivaris*) captured in the lower Thames River, 2016–2018, by Fisheries and Oceans Canada's Asian Carp Program.

Historical records of Flathead Catfish captured in Canada before 2001 were speculated to be individuals that dispersed from a known population in the Huron River, Lake Erie, and gained access to Lake St. Clair through the Detroit River (Goodchild 1993; COSEWIC 2008). The juvenile Flathead Catfish captured in our study would not likely be able to disperse from a Lake Erie tributary upstream through the strong-flowing Detroit River, providing further support for the likelihood that these individuals were the result of reproduction in the Thames River. Few studies have examined the movement of juvenile Flathead Catfish. Travnichek (2004) found a relationship between Flathead Catfish size and movement in the Missouri River: as size increased so did distance travelled. In their study, Flathead Catfish that were 305–380 mm TL travelled an average of 4.6 km in up to two years after tagging (Travnichek 2004). Stocking is an unlikely alternative method of introduction of the individuals captured here, as there is no documented stocking of Flathead Catfish in Ontario and, in the United States, Flathead Catfish are most often stocked as adults (Guier *et al.* 1981; Jenkins and Burkhead 1994). Introduction through the live fish trade is also unlikely, as there is no record that live Flathead Catfish have been imported into Canada (Mandrak *et al.* 2014) and surveys of six live fish markets and 20 pet stores in the Great Lakes region did not report Flathead Catfish (Rixon *et al.* 2005).

Flathead Catfish may be more abundant in the Canadian waters of the Great Lakes basin than currently known, and its range is likely not fully documented because of its cryptic behaviour and difficulty to sample (Goodchild 1993; Fuller and Whelan 2018). Continued Asian carp surveillance will further document the Flathead Catfish population in the Thames River. This work is also being conducted in 35 other locations in the Great Lakes basin and may provide information on new locations of Flathead Catfish populations.

The potential impacts of Flathead Catfish in the Great Lakes basin are unknown and should be further investigated to determine how this species should be managed. Pine *et al.* (2005) found that Flathead Catfish is primarily piscivorous, feeding on the most abundant fishes in rivers, which could lead to a change in local food-web structures. The presence and increased abundance of Flathead Catfish has been associated with decreases in the abundance of sunfishes (*Lepomis* spp.; Davis 1985; Thomas 1993; Bart *et al.* 1994; Ashley and Rachels 1998; Bonvechio *et al.* 2009), black basses (*Micropterus* spp.; Thomas

1993; Bonvechio *et al.* 2009), redhorses (*Moxostoma* spp.; Bart *et al.* 1994), Common Carp (*Cyprinus carpio*; Davis 1985; Bart *et al.* 1994), and bullheads (*Ameiurus* spp.; Davis 1985). Flathead Catfish may have some ecological benefits in the Great Lakes basin, as a predator of the invasive Common Carp and as a known host for Mapleleaf mussel (*Quadrula quadrula*; Howard and Anson 1922), which has been listed as special concern under the Canadian *Species at Risk Act* (SARA Registry 2019). The Thames River is thought to have the largest population of Mapleleaf in southwestern Ontario, and recent records of Flathead Catfish overlap with records of Mapleleaf from the lower Thames River in 2005 (COSEWIC 2016). Flathead Catfish has seasonally varying home ranges and movement patterns (Daugherty and Sutton 2005a), which are important characteristics of hosts that facilitate the genetic mixture of freshwater mussel populations in rivers (Elderkin *et al.* 2007).

The distribution of freshwater fishes is often restricted by temperature. Mandrak (1989) determined that Flathead Catfish had low potential for future expansion into the Great Lakes basin because of thermal restrictions. With climate change, the water temperature of the Great Lakes is expected to increase 2–3°C in southern Ontario and 3–4°C in northern Ontario by 2065 (Gula and Peltier 2012). Such an increase will benefit warm-water species, such as Flathead Catfish, by increasing recruitment success (Casselman 2002; Chu *et al.* 2005; Hansen *et al.* 2017). This increase in recruitment has the potential to expand the range of Flathead Catfish and lead to a greater abundance of the species in the Great Lakes basin (Casselman 2002).

Our research suggests that a better understanding of the potential ecological impacts and improved distribution modelling of Flathead Catfish in Canada is required. With climate change, many species are likely to undergo range expansions, bringing new threats to already imperilled native species. With limited resources, managers must balance this with the threats of new (or existing) invasive species that have a greater potential for damage (Rahel and Olden 2008; Rolls *et al.* 2017). In Canada, there is a need for clear management objectives for these species undergoing natural "invasions", that include consistent classification and terminology and a framework to prioritize them (Chu *et al.* 2005; Rahel and Olden 2008).

The capture of Flathead Catfish representing at least five age classes, including young-of-year fish, is a strong indication that reproduction has occurred in the lower Thames River. With the recent captures reported here, there may now be sufficient data for Flathead Catfish to be re-assessed by COSEWIC. Additional research targetting Flathead Catfish is recommended to (i) better understand the distribution of this species in Canada, (ii) evaluate the most effective gear for detection, (iii) estimate abundance, and (iv) understand the movement and habitat-use patterns in the Canadian waters of the Great Lakes basin.

Author Contributions

Writing – Original Draft: C.I. and J.E.C.; Writing – Review & Editing: C.I., J.E.C., N.E.M., and D.M.M.; Methodology: C.I., J.E.C., and D.M.M.; Visualization: C.I. and J.E.C.

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The Canadian Field-Naturalist

Book Reviews

Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Currency Codes: CAD Canadian Dollars, USD United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pounds.

Entomology

Buzz, Sting, Bite: Why We Need Insects

By Anne Sverdrup-Thygeson. 2019. Simon and Schuster. 235 pages, 35.00 CAD, Cloth.

Buzz, Sting, Bite is another entry into the growing list of accessible popular science books written as passion projects by an academic researcher. A professor of conservation biology at the Norwegian University of Environmental and Life Sciences and a scientific advisor to the Norwegian Institute for Nature Research, Sverdrup-Thygeson's specialty is the ecological role of insects in trees and forests, but the book covers arthropods and their ecological roles more broadly. In addition to a multitude of interesting facts, it includes some discussion of broader conservation ecology, such as habitat connectivity, extinction debt, and endangered species. As promised by the tagline "why we need insects", the work also delves into humanity's ties to the insect world, from 13th century Chinese cricket fights to termites eating their way through stashes of bank notes.

Organized into nine main chapters, the scope is broad and about what you would expect from the outset: anatomy, mating, agricultural food systems, the ecological role of detritovores, and insect-human interactions. While each chapter has a stated theme, they are further divided into multiple sections and subsections. Overall quite intuitive and well managed, this structure does pose narrative challenges and can become disjointed at times as topics begin to blur together. One key advantage of this bite-sized-piece approach is that like many books written for popular audiences, it makes for easy reading; this book may not pull you in for an all-night reading binge but it is well designed to be picked up at your leisure.

Artfully translated by Lucy Moffatt from the original Norwegian 2018 publication, *Buzz, Sting, Bite* includes some truly excellent explanations and turns of phrase. Although there are a few notable oversimplifications when discussing the natural history of insect groups and genera (e.g., bumble bees), the writing is at its best when it focusses on the truly weird and wonderful. Chapter 7, From Silk to Shellac: Industries of Insects, was by far my personal favourite, galloping across time periods and cultural traditions to bring together everything from oak gall wasps and historical records, silk production, bulletproof vests, and the Aztec and Mayan traditions of breeding cochineal bugs. To my repertoire of offbeat insect-based cocktail conversation I can now add the link between shellac, phonograph records, and a 1942 restriction ordered by the United States government on the record industry to reduce shellac consumption by at least 70%—for this I am forever grateful.

The main text is complimented by black and white illustrations by artist Tuva Sverdrup-Thygeson, one at the beginning of each chapter matched to its overall theme. These are welcome additions, as is the list of eight other author-recommended popular science insect books found under Further Reading following the Acknowledgments section. Although no in-text citations are provided, a bibliography of sorts is

found in the 20-page Sources section which is organized by chapter and includes full citations of journal papers, reports, books, and popular science articles. The text ends with a detailed Index, so when you inevitably want to refresh the details on a specific fact or anecdote it is at your fingertips.

One of the author's objectives in writing this book is to shine a spotlight on the creepy-crawly things of the world and shower them with the praise and appreciation that they deserve. In highlighting their value to human societies and their intrinsic 'cool' factor (even going so far as to use that rarest punctuation mark, the exclamation point, on several occasions), the author is largely successful. Although I doubt that those with a serious bug phobia will be drawn to this book, the range and variety of topics covered means that there is probably something here for everyone. Human-insect-avian interactions? Take Greater Honeyguide (*Indicator indicator*) birds and their collaboration with the Yao people of Mozambique. Urban ecology and localized natural selection events? Have a side of mosquito speciation by station area of the London Underground. Want to hop on the insect eating bandwagon? You'll find it espoused here, if only briefly. Reading *Buzz, Sting, Bite*, I was reminded why I enjoy reading books on broad topics written by good writers—the more I learn, the more I want to know. This book provides more breadth than depth when it comes to bug love but is an excellent jumping off point for those who want to dive deeper, and a great toe dip for any who may otherwise hesitate to even approach the water's edge.

HEATHER A. CRAY
Halifax, NS, Canada

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Butterflies: Their Natural History and Diversity. Second Edition

By Ronald Orenstein. Photography by Thomas Marent. 2020. Firefly Books. 24.95 USD / CAD, Paper.

A quick internet search appears to confirm the easy notion that butterflies must be the most popular of the insects. I think of them as the birds of the insect world, often colourful, active, and highly visible. And, as with birds, the internet is full of books, posters, calendars, etc. related to butterflies. One might wonder at the need for yet another book, but given the popularity of the topic, it comes as no surprise. And this one delivers the goods in an informative, accessible way.

The photographs catch the eye first. Swiss photographer Thomas Marent is a well-travelled wildlife photographer who, starting young, has about 40 years experience in shooting pictures of various forms of wildlife that have been featured in a number of books, including the first edition of this one, an earlier book with Orenstein, and an earlier one yet of his own. The photos are consistently gorgeous, crisp in their detail, and beautifully presented.

It would be very easy—and a big mistake—to treat this as a picture book! Ronald Orenstein is a Canadian zoologist/ornithologist, lawyer, wildlife conservationist, and prolific author/editor of natural history books. He admits in the Acknowledgements that he is "not an entomologist" (p. 224) but the text reveals an enviable capacity for digesting the latest research. The book opens with a lengthy introductory outline of lepidopteran natural history that ranges from the origins of the term 'butterfly' and their cultural significance through their evolutionary history and brief description of the six families into which they are now organized. The book covers wing formation and function, mimicry, mating and reproduction, host plants, development from egg to adult phases, issues of conservation, and much more. Orenstein isn't shy about using scientific names and terms—androconia, for example—that are always defined in the text.

We learn some surprising things, such as why butterfly flight is erratic (pp. 9–10), the various types and roles of wing scales and the genetic coding that produces their colours (p. 11), that mimicry in a particular species can vary in time and place, the well-known Viceroy being an example (p. 13). Nuptial gifts and sperm competition (p. 16), pollination, migration, and DNA-based discoveries all receive concise, research-based accounts. One of the most interesting things I learned was that these lovely insects that can be such innocent symbols of beauty and grace are capable of cannibalism and manipulative deception in symbiotic relations with other animals such as ants.

Chapters 1 through 6 discuss the six families and their subfamilies, each of which receives brief introductions. The photographs of species come into their own here, each identified with scientific name and location, followed by brief and informative comments on topics such as distribution, habitat, caterpillar stages, and toxicity. The next four chapters are thematic, profusely illustrating and adding to the themes of the introduction: Butterfly Wings (Chapter 7), Butterfly Life History (Chapter 8), What Butterflies Eat (Chapter 9), and Butterflies in Their Environment (Chapter 10). The 11th and concluding chapter, Myriads of Moths, reminds us that "butterflies are moths" (p. 6) after all. Moth species "outnumber butterflies by at least fifteen to one" so this chapter is "a miscellany, not a survey…" (p. 185). And a handsome survey it is, covering some spectacular examples, the caterpillars being particularly fascinating.

The book concludes with a page of Further Reading that lists books and websites, plus a URL for the "400+ papers consulted…" (p. 219), and an Index. One odd thing: the book has two covers, the new one you can see here, and a reproduction of the original cover; it is this one, not the new cover, that says Second Edition. A minor puzzle for a worthy book. Books on butterflies seem to be written for professional lepidopterists or for kids, with many popular 'picture books' in between. This book is one of the comparatively few that focus on natural history for the interested generalist who has some background in the topic. Orenstein and Marent have created a fine addition to such a reader's library, one that informs while pointing the way to further study.

BARRY COTTAM
Ottawa, ON, and Corraville, PE, Canada

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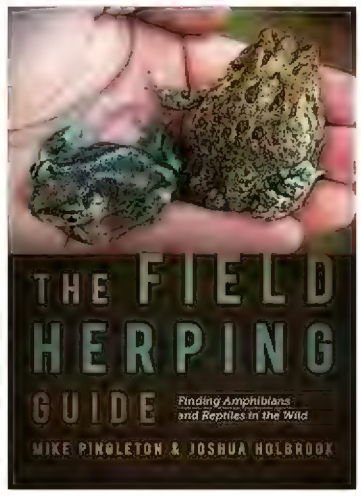
HERPETOLOGY

The Field Herping Guide: Finding Amphibians and Reptiles in the Wild

By Mike Pingleton and Joshua Holbrook. 2019. University of Georgia Press. 264 pages, 26.95 USD, Paper.



An increasing number of people are interested in amphibians and reptiles, or 'herps', and this interest includes wanting to see them in nature. Many of these species can be somewhat challenging to find and a guide to finding herps is a good idea. *The Field Herping Guide* does just this as well as discussing issues one should keep in mind to keep the herpers and the herps safe. It should be stressed that this is not a book about how to conduct scientific surveys of amphibians or reptiles or how to design field ecology studies, this is a guide to finding herps for fun.

The book consists of nine chapters with lots of colour photographs. The chapter titles are a good indication of the topics the book covers: Getting Started; Understanding Herp Behavior; Finding Herps; Catching and Handling Herps; Safety in the Field; Ethics and Etiquette, Rights and Responsibilities; Classification, Taxonomy, and Species Identification; Citizen Science and Data Collection; and Herp Photography. Several appendices on topics such as diseases, various kinds of public lands (mainly from an American point of view), internationally known herp hotspots, herp education, and the history of field herping round out the book.

Is this a valuable book? The book is easy reading, but still contains a lot of information. Much of the advice seems very general, such as sometimes it is too hot for herps to be active, or often herps are active during or after it rains. Given the wide range of species covered, from salamanders to snakes, it is hard to generalize about herps. The authors do a good job of tackling each group of species, but even here the diversity is greater than many people realize. Salamanders can be completely aquatic and never leave the water, live along and in streams, depend upon temporary wetlands for breeding, or live in forests with no need of aquatic habitats. Overall, the authors provide useful advice on the diversity of lifestyles and guidance for how and when to survey for different sub-groups of species.

Unfortunately, the book also has many problems. A book that covers searching for venomous snakes should emphasize safety. The authors discourage people from catching venomous snakes and provide cautions about getting too close when photographing them, but then include a photo of someone in shorts and sandals with a snake hook and a venomous snake (p. 11). This is not the kind of lax safety precautions the authors should be encouraging. And despite urging people not to catch venomous snakes the authors provide several methods for capturing venomous snakes (pp. 113–116).

I also caught a surprising number of factual errors in the book. In the section on crocodilians, the authors give the distribution of Morelet's Crocodile (*Crocodylus moreletii*) as being limited to Mexico and Guatemala but omit Belize (p. 89). In the section on frogs, it is incorrectly stated that cricket frogs (*Acris* spp.) are ranids or true frogs, when, in fact, they are hylids or treefrogs (p. 93). The authors state that Wood Frog (*Lithobates sylvaticus*) is the only herp in Alaska (p. 94), but this is not even remotely accurate as there are five other native amphibians.

There are also a few things the authors could have stressed more. Near the beginning of the book the authors mention that insect repellant can be toxic to amphibians (p. 18) but this fact is not mentioned again in the section on catching frogs (p. 126). Nor is there any mention of sunscreen on hands which can also be toxic to amphibians.

I hope the authors prepare a second edition which corrects these things. While this book is not going to teach experienced herpetologists much about searching for herps, it is a great introduction to field herping for those who are keen about herps but don't have much experience. Even with the errors in this book it could still be a valuable resource at school libraries where it could kindle passion in a young reader.

DAVID SEBURN
Ottawa, ON, Canada

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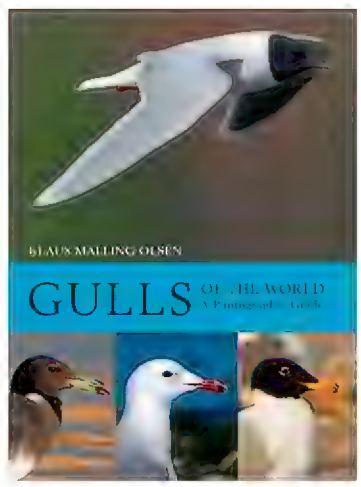
ORNITHOLOGY

Gulls of the World: A Photographic Guide

By Klaus Malling Olsen. 2018. Princeton University Press. 368 pages, 65 maps, and 600+ colour pictures, 45.00 USD, Cloth.



As has been frequently noted, gulls can be a real pain to identify because, not only are many of the species very similar, but they exhibit changes of plumage with age to a greater degree than any comparable group of birds. Consequently, they deserve, and have received, much attention in the form of identification guides specific to the group, starting with Peter Grant's (1982) classic, *Gulls: A Guide to Identification*. They continue to attract enormous attention from birders, especially now that hybridization among species is known to be extensive. Facebook groups and 'twitterati' agonise over the identity of individual birds (... probably a Western × Glaucous-winged ... almost certainly a second winter Thayer's Gull ...), sometimes long after the bird has flown off into the sunset.

Fifteen years ago, Klaus Malling Olsen, along with the artist Hans Larsson, produced a monumental, 608-page guide to the gulls of the northern hemisphere (Olsen and Larsson 2003) which dealt with their identification, voice, moult, plumage, and distribution, including detailed range maps. The current book is a revision and expansion of the earlier book, although with much less detail on topics other than identification. In place of Larsson's plates, the book is illustrated entirely with photographs, which, as pointed out by another reviewer, are an improvement on those in the first book. In fact, the book comprises an unmatched collection of gull portraits and, as such, is an unmatched resource for identifying gulls in the field.

Given the global spread of e-Bird since the earlier book, you might have expected an improvement in range maps as well, but I did not find that to be the case. The colour code in the current volume consists of yellow for breeding range, blue for wintering range, and green for "if no wintering area shown, occurrence all year" (p. 29). In fact, I found no green areas on any maps. Consequently, where breeding and wintering areas overlap, as for American Herring Gull (*Larus smithsonianus*) on the Great Lakes, the reader cannot tell where the northern limit of the wintering area is. Some rather strange errors in the maps have been perpetuated from the earlier book, including the breeding colony of Black-legged Kittiwakes (*Rissa tridactyla*) at Cape Cod (unnoticed so far by North American ornithologists) and the swath of Ivory Gulls (*Pagophila eburnea*) supposedly breeding across the western Queen Elizabeth Islands.

Because of extensive hybridization among gull species, their taxonomy is contentious. For example, Olsen treats Thayer's and Iceland Gulls (*Larus thayeri, Larus glaucoides*) and American and European Herring gulls (*Larus smithsonianus*, *Larus argentatus*) as different species, whereas the American Ornithological Society now regards Thayer's as a subspecies of Iceland (*L. g. thayeri*) and continues to treat North American Herring Gulls as conspecific with their European counterparts. Since Grant's book in 1982, four species dealt with here have been carved out of his "Herring Gull".

One small reservation I have about treating this book as the last word on gull identification (a reservation I also hold about the opinions of many experts that I read on the web) is that few of the contentious identifications are backed up by genetic material. Consequently, I cannot see how many of the identifications can be treated as better than 'best guesses'. One of the problems of a book like this is that someone might find a gull in the field identical to one of Olsen's pictures and consequently feel confident in the identification. But what if Olsen was wrong? Peter Adriaens and Amar Ayyash, on the American Birding Association website, give a list of errors that they found, including several identifications that they consider erroneous (http://blog.aba.org/errata-gulls-of-the-world). Nothing is perfect and we need to keep that in mind. In science, all is provisional.

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TONY GASTON
Ottawa, ON, Canada

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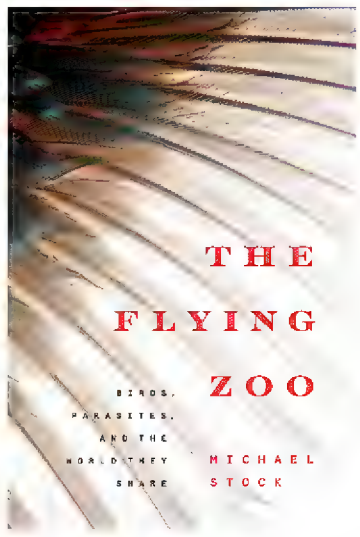
ZOOLOGY

The Flying Zoo: Birds, Parasites, and the World They Share

By Michael Stock. 2019. University of Alberta Press. 260 pages, 29.99 USD, Paper



Michael Stock's book, *The Flying Zoo: Birds, Parasites, and the World They Share*, provides an intriguing glimpse into the lives of birds and their parasites, which are usually looked upon with disgust and dismissed as worthless vermin. However, parasites may provide benefits to their hosts, and Stock's narrative breathes new life into the world of these often-misunderstood organisms. The author asks "How has this weird association between one organism (a bird) and its fellow travelers (parasites) become normal? What special adaptations have parasites had to evolve to be able to find, colonize, and survive in or on their hosts? … How have hosts evolved to survive with their 'zoological garden'?" (p. 4). These questions, and many more, are examined and explored with vigour and enthusiasm.

The book is divided into 10 chapters: A World on a Bird; Lice: It's a Beautiful Life; Fleas: The Circus in the Zoo; Tough Ticks; Mites: Little Things Mean a Lot; Flying Zoo Flies; The Worms that ate the Bird; Oddities in the Flying Zoo; Flying Zoo Behaviour; and Environmental Impacts: The Future of the Flying Zoo. Also included are a Notes section, Further Reading References, and an Index. More than 30 highly detailed pen and ink illustrations of the parasites in question are also dispersed throughout the book.

The book is a joy to read; the author crafts a fascinating journey into the lives of birds and their parasites using current research cases, vivid descriptions, and subtle humor. Co-evolutionary themes are commonplace and connect ecology, biology, adaptation, and survival into a seamless narrative. The reader travels the world, from Madagascar to the Americas, exploring the various interactions between parasite and host. Some amazing information comes to light from Stock's research: who knew that fleas could sing or that there is a specialized moth that drinks the tears of sleeping birds? One of the perks of the book is that the author defines various biological terms (sometimes breaking down the Latin or Greek root words), a major help to those first encountering the term or a refresher for seasoned naturalists and biologists.

All of the classic parasitic groups are covered, including fleas, ticks, lice, flies, and worms. However, peripheral species are also addressed, such as bed bugs (but for birds), moths, leeches, and strange critters called tongue worms. Figure 1.1 on p. 3 illustrates the parasitic relationship with birds well: it shows a Common Pigeon (*Columba livia*) surrounded by various parasitic species that may occur on and within a single bird, from roundworms, flukes, and tapeworms occurring inside the bird to mites, ticks, fleas, and lice occurring on the outside, each occupying a specialized niche (hence the idea of a "flying zoo"). One of the more fascinating topics Stock explores is the niche theory, which states that in order to reduce direct competition, species evolved to occupy different habitats or feeding behaviours. For example, a single bird may support several species of lice, but these lice live in different parts of the bird, such as on various locations of the wing (either on the feathers or inside the quill), on the head, or near the skin. In addition, these lice evolved different body shapes in order to avoid being detected or removed by the bird during the preening process.

It is unwise to assume parasites are worthless creatures with no value, and Stock provides several examples. Worms, such as blood flukes, have evolved ways to not be attacked by the host bird's immune system by down-regulating the immune response. Humans with auto-immune diseases may benefit in the future when we figure out how flukes and other parasites alter host immune systems (p. 150). Leeches, in another example, have a protein anticoagulant in their saliva called hirudin. The anticoagulant is now commercially produced and used to treat people with cardiovascular problems (p. 166). In addition, sometimes parasites provide advantages to their hosts. For example, wild Mute Swans (*Cygnus olor*) have a mature community of co-evolved helminths (worms). Mute Swans in a zoo environment, on the other hand, are not exposed to their usual worm parasites and were infected with two rare tapeworm species causing major infections and significantly diseased birds. The normal worm parasites are apparently a benefit to the swan by preventing harmful helminths from infecting the host. The co-evolved relationship between parasite and host seems to lead to a peaceful co-existence (p. 143). In another example, feather mites may benefit hosts by eating bacteria and fungi trapped in preen gland oil. These bacteria and fungi, in large numbers, may make a bird look unhealthy or diseased, but the

mites, by consuming these organisms, allow a bird to appear to have bright and healthy plumage, aiding in their reproductive success (p. 182).

Co-evolution between hosts and parasites is not novel. A few "rules" have been established by researchers exploring the idea. The first, known as Fahrenholz's Rule, claims "that parasite evolutionary histories, or phylogenies, should mirror the histories of their hosts" (p. 142); that is, hosts that are related evolutionarily may harbour the same parasites. A second rule, called Manter's Rule, states "that long associations between hosts and parasites should lead to strong host specificity" (p. 142) and that "parasites should speciate more slowly than their hosts" (p. 24). The third rule, Eichler's Rule, states that "a large taxonomic group of hosts … should have more genera and species of parasites than a small taxonomic group" (p. 24). The fourth rule, Szidat's Rule, claims "more recent or specialized host groups should have more recent or specialized parasites while more primitive or generalized hosts should have more primitive or generalized parasites" (p. 24). Finally, Harrison's Rule states that "large-bodied species of hosts should have large-bodied parasites" (p. 24). Indeed, Stock explores these relationships throughout the book.

Overall, the book is a must-read for those interested in the intricate and interwoven world of birds and their parasites. The author emphasizes that it would be a mistake for anyone interested in avian biology to ignore that parasites are a real and significant part of the lives of birds. Parasites influence many aspects of the lives of our feathered friends, from sexual selection to healthy co-evolutionary relationships. A bird parasite may be harmful, beneficial, or indifferent, and any single parasite can fulfill any one of these roles to all three. Host-parasite studies will continue to lead to more questions and puzzles, especially with the looming climate change crisis, and Stock has provided a good starting point on this journey with his book *The Flying Zoo.*

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HOWARD O. CLARK, JR.
Colibri Ecological Consulting, LLC,
Fresno, California, USA

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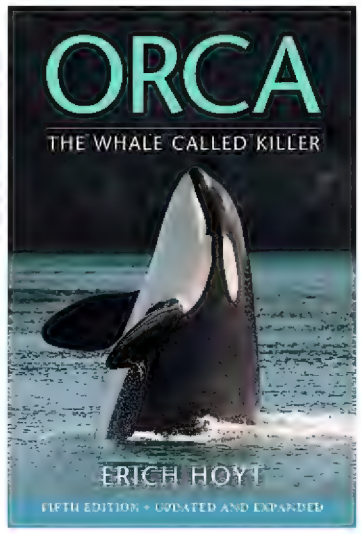
Orca: The Whale Called Killer. Fifth Edition

By Erich Hoyt. 2019. Firefly. 320 pages, 24.95 USD, Paper.



Orca: The Whale Called Killer is a really great read. Erich Hoyt has been studying whales for a long time, and his knowledge of the Killer Whale (or Orca) shines through in this book. Hoyt leads readers through his first three summers (1973–1975) documenting Northern Resident Killer Whales around Johnstone Strait, northern Vancouver Island. Hoyt and his colleagues were filming, photographing, and recording the underwater vocalizations of Killer Whales to make documentaries on them. At this time, very little was known about Killer Whales. For example, now we know that there are four different types of Killer Whales in British Columbia (BC): the northern and southern populations of resident, salmon-eating ecotypes; the transient, mammal-eating ecotype; and the offshore shark specialist ecotype. But in 1973, biologists did not know that these Killer Whales were different. The book focusses on the timeline of Hoyt's exploits in the field, including how he learned new things about Killer Whales during his adventures. This book is partly set up like a field notebook or diary, with frequent excerpts from Hoyt's field notes, which I found an effective style to portray the story. This is the fifth edition of the book, but according to Hoyt, the last substantial update occurred in the 1990 version (third edition), so this new edition adds information gleaned about Killer Whales over the past 30 years. This new edition has a new introduction detailing important events that have happened with Killer Whales since the 1990 version of this book. It also includes an expanded afterword, epilogue, and bibliography.

Hoyt's tales of whale watching in the wild are also interwoven with the looming reality of Orca capture events that were happening concurrently. At this time, Killer Whales in BC and Washington State were actively being captured and sold to aquaria worldwide. In many ways, the live capture events of Killer Whales and the early days of Orcas in captivity are what sparked Hoyt's interest in spending entire summers on the water to learn about the wild whales that were barely known by science at the time. Hoyt's first years in the field also happened at the same time and in the same locations as famed Killer Whale biologist Michael Biggs, who collected incredibly important information for the Canadian government about all of the Killer Whales along the coast of BC, which helped lead to the end of the live capture of Killer Whales in Canada. The historical context of this book is one of its great features.

My favourite part of this book is the way that Hoyt brings everything together in the final chapter. Hoyt was a huge proponent for an ecological reserve that was established for these Killer Whales in Robson Bight, and in this final chapter he discusses a lot of the rationale for why and how that process actually happened. Since Hoyt's early days of studying Killer Whales, he has become a global proponent for marine protected areas as a tool for conserving whales, and his early work on this ecological preserve on northern Vancouver Island clearly paved the way for his future work on marine protected areas.

This book would be a great read for any naturalists interested in learning about Killer Whales, both the natural history of populations in BC, but also the history surrounding their conservation and protection in Canada. This may be of particular interest to those who have been following the recent efforts of Fisheries and Oceans Canada to study and protect Southern Resident Killer Whales, which are closely related to the Northern Resident Killer Whales that Hoyt followed in this book. For those interested in a comparison between Killer Whales in the wild versus those in captivity, this book also provides a lot of useful context.

WILLIAM D. HALLIDAY
Wildlife Conservation Society Canada,
Whitehorse, YT, and
Department of Biology, University of Victoria,
Victoria, BC

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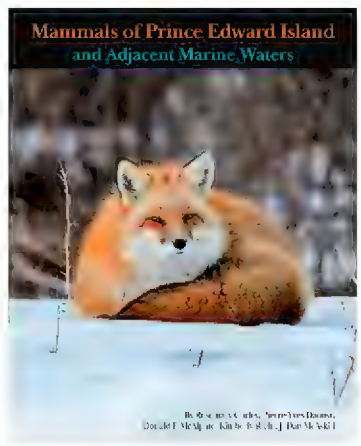
Mammals of Prince Edward Island and Adjacent Marine Waters

By Rosemary Curley, Donald F. McAlpine, Dan McAskill, Kim Riehl, and Pierre-Yves Daoust. 2019. Island Studies Press. 354 pages, 49.95 CAD, Paper.



Ok, go ahead, judge this book by its cover … it is quite stunning! A Red Fox (*Vulpes vulpes*), seemingly just aroused from its slumber to look at the photographer … its tail wrapped around itself, while resting on the snow … what a perfect shot to entice a shopper to take a copy off the bookstore shelf!

This is a thorough book—over 1000 references were used! The introduction provides a background and synopsis of Prince Edward Island's mammals, covering both extirpations and (re)introductions. Large-scale factors influencing mammals, including climate change and white-nose syndrome, are introduced; these are treated in more depth further in the book. Here, domestic animals are given mention, and dismissed from further representation in the book.

This book covers 57 species of mammal, essentially split evenly between the marine and terrestrial environments. I believe one is missing, but I'll defer that discussion. Each account includes a colour illustration of the animal, a range map (North American distribution, or beyond), and a diagram of the skull from three perspectives (dorsal, palatal, and lateral). Sometimes, there is also a photograph. For most non-volant, terrestrial species, at least one trackway, and an accompanying more-detailed illustration of a hind and fore footprint, are included. Five of these trackways appear only as series of irregular grey shapes, clearly a printing error, for which there was no excuse; one hopes that a second printing clears this up.

The text for each account is very well organized and the writing is clear and consistent, not a small feat for a book with so many authors. Short sections include description, range, and status (now and earlier) whereas most of the accounts encompass the species' ecology, often running several pages. History on the island is detailed, which, when appropriate, includes introduction and extirpation dates and details of these events.

The missing species from this book is the Domestic (free roaming) Cat (*Felis catus*). Other introduced species are included—Bobcat (*Felis rufus*), Brown Rat (*Rattus norvegicus*), Eastern Gray Squirrel (*Sciurus carolinensis*)—so why not the infinitely problematic free roaming house cat? In Prince Edward Island, just like other jurisdictions, there are not only individuals who let their cats run amok, there are still those misguided people who promote supported colonies of these wildlife destroyers. Omitting the Domestic Cat from this book was a missed opportunity for further education.

This book is well-suited to people with a general interest (an extensive glossary was included, and will be much appreciated), but adept naturalists will still learn a lot. The previously mentioned voluminous reference section will serve as a start to finding more information for mammal enthusiasts of any level.

RANDY LAUFF
Biology, St. Francis Xavier University
Antigonish, NS, Canada

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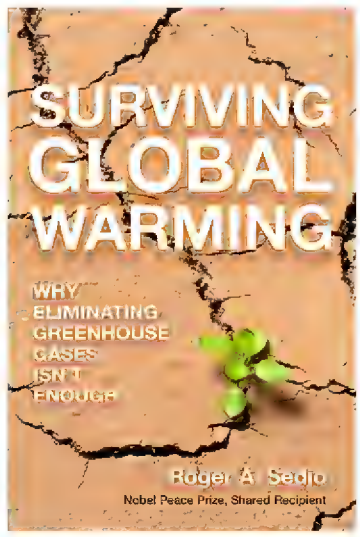
OTHER

Surviving Global Warming: Why Eliminating Greenhouse Gases Isn't Enough

By Roger A. Sedjo. 2019. Prometheus Books. 245 pages, 24.00 USD, Cloth, 22.50 USD, E-book.



Dr. Roger Sedjo is a Senior Fellow Emeritus at the environmental think tank Resources for the Future in Washington, DC. He specializes in forestry and policy, holds several honourary degrees, awards, and fellowships, and shared the 2007 Nobel Peace Prize for his work on the Intergovernmental Panel on Climate Change (IPCC) Climate Assessments. Despite these qualifications, I struggled through this book.

The core argument is straightforward: climate change is inevitable and will have dramatic, unavoidable impacts on human society. Even our most ambitious mitigation solutions will not stop this inevitability, so we must invest in adaptation solutions. For anyone engaged in the climate change conversation, this is not a new idea: most government climate change strategies in Canada recommend both mitigation and adaptation measures. Climate change adaptation is not controversial, so I am puzzled by Dr. Sedjo's insistence that to justify adaptation efforts, he must discredit the need for mitigation.

Sedjo dedicates the first third of the book to scrutinizing what he calls "Al Gore's theory of global warming" (Chapter 1, Al Gore and the Greenhouse Gas Theory: Plan A), that is, the theory that recent climate change has been caused by increases in greenhouse gas (GHG) emissions from humans. He seems to think that if he can convince the reader that the climate is changing at least in part from natural causes, then the reader will also be convinced that mitigation is a waste of time: if GHG emissions are not the entire problem, GHG reduction cannot be the whole solution. I cannot help but recall Joel Pett's well-known political cartoon from 2009 depicting delegates at a climate summit: "What if it's a big hoax and we create a better world for nothing?"

In order to cast doubt on "Gore's theory", the author spends quite a bit of time discussing evidence of natural climate change, including the existence of the medieval warming period in the climate record and the role of solar cycles (see Chapter 2, Natural Climate Change: GHG's Are Not the Whole Answer). He writes that "solar energy is not currently viewed as a major contributor to today's warming by the IPCC. However, solar factors are still not yet well understood" (p. 37). Out of curiosity, I googled "Is the sun causing climate change?" The first result, from the National Aeronautics and Space Administration (NASA), starts off this way: "No. The Sun can influence the Earth's climate, but it isn't responsible for the warming trend we've seen over the past few decades" (National Aeronautics and Space Administration 2020). Around this point I started to lose patience for his deep-dives into the medieval warming period and frustrating lack of understanding when it comes to basic climate science, for example: "How rapidly will land-based glaciers melt, and will future snows offset much of that melting?" (p. 18). (The answer is no—warming temperatures will offset any possible increases in snowfall because the melting will outpace the rate of accumulation [National Snow & Ice Data Centre 2020].) There is so much repetition of the same poorly referenced material that I often had the disorienting feeling that I had read the same paragraph multiple times.

The bulk of the book—Chapters 4 through 8—is dedicated to "Plan B: The Adaptation Solution". Some of Sedjo's ideas are reasonable: for example, he writes about the importance of coastal habitat protection to buffer sea level rise (p. 103). But as an ecologist, I find many of his ideas disturbing. In his discussion on the relative albedos of different surface types, he writes: "So, Mother Nature being complicated, those who are cutting down the Amazon rainforest could be seen by some as countering global warming instead of aggravating" (p. 153). I'm still not clear if that is supposed to be a joke or not.

The section on geoengineering (Chapter 5) is a litany of potential projects that sound rather extreme: carbon capture and storage, seeding the atmosphere with sulphur dioxide, or "moderating the atmosphere with calcium carbonate particles" (p. 145). This insistence on adaptation over mitigation confuses me, because, even from a strictly economic viewpoint, minimizing our GHG emissions now will make adaptation in the future cheaper because there will be less carbon in the atmosphere. The only answer I came up with is a fear of the drastic changes that must occur to transition away from a fossil fuel economy.

In the final pages, Sedjo states that natural gas could be the remarkable solution that we need; it's a bit anti-climactic. Even Sedjo admits that "in the long term, it is only a part of a more environmentally friendly energy transition. The question is: a transi-

tion to what?" (p. 208). Now *that* sounds like the first line of a book that we need today.

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EMMA BOCKING
Halifax, NS, Canada

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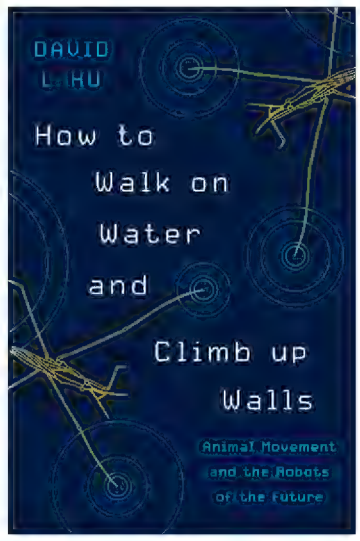
How to Walk on Water and Climb up Walls: Animal Movement and the Robots of the Future

By David L. Hu. 2018. Princeton University Press. 240 pages, 24.95 USD, Cloth or E-book.



Albert Einstein (1955: 64) once said that "The important thing is not to stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery every day". One can keep thinking about curiosity towards all aspects of life while reading *How to Walk on Water and Climb up Walls: Animal Movement and the Robots of the Future*.

In his book, David L. Hu, an associate professor of mechanical engineering and biology and adjunct professor of physics at Georgia Institute of Technology, tells us about his research and through that teaches us how to maintain curiosity and approach research questions. Specifically, in his research he tries to find and focus on the principles of animals' movements and apply these to robots. However, the book does not cover all animal motions, but generally those on which the author has done experimentations. For example, in the first chapter he shows us how the water strider's motion and ability to stand on water has inspired a water-walking robot. And in the second chapter we learn about the principles of crawling animals' (snakes and sandfish) movements. Next, Hu tells us about animals (e.g., jellyfish) that use their body parts to influence the flow of fluids for their own advantage. We learn about surface structure of animal bodies such as sharkskin (Chapter 4), and body structures (Chapter 5) that could be used to develop machines that are capable of moving underwater or on land with decreased energy expenditure or to design wearable devices—exoskeletons—that could lower the energy costs of human walking.

In the sixth chapter we learn how insects deal with collisions and how engineers are inspired by these insects as potential applications to robots. For example, how mosquitoes survive being struck by raindrops, bees survive crashing into obstacles such as flowers and plants, and cockroaches squeeze themselves into very narrow spaces. Then the author tells us how animals automatically respond to their surroundings, using the examples of flies overcoming turbulence during their flight and the cockroach's ability to measure its distance from the obstacles during quick running (Chapter 7). Finally, we learn about ants' ability to link their bodies to create a flow like liquid, form bridges, or spring back like a solid.

How to Walk on Water and Climb up Walls is interesting for those curious minds learning how one can do experimentation, as throughout the book Hu details the steps of his experiments and how he has overcome the problems during the process of experimentation. This book is for general readers interested in scientific inquiries as it teaches the way one should pursue them. It is full of colourful stories, a joyous read for curious minds, making it an easy read for laymen and even school students.

The book is written from an engineering rather than a biological perspective and one may speculate about evolutionary and adaptive mechanisms while reading the book. Hu writes that "animal motion is all around us. It is the principal way animals get things done in the world. How did such a diversity of animal movements come about?" (p. 4), but the book does not tell us how these animals might have adapted and does not therefore generalize for other species.

Altogether, the book is for general readers interested in learning how scientific inquiry should work and how a scientist thinks and does experiments. That is a very interesting, fun, thought-provoking, story-based, and amusing book for undergraduate and high school students interested in physics, robotics, fluid mechanics, mechanical engineering, and related disciplines.

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FARID PAZHOOHI
Department of Psychology, University of British Columbia, Vancouver, BC, Canada

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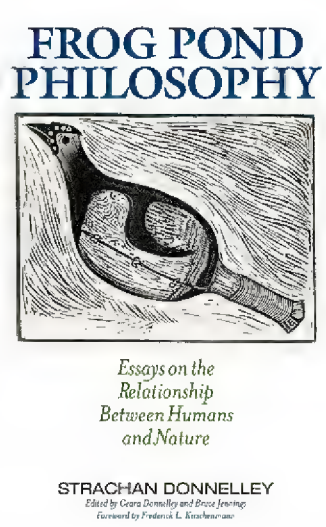
Frog Pond Philosophy: Essays on the Relationship Between Humans and Nature

By Strachan Donnelley. 2018. University Press of Kentucky. 248 pages, 38.17 CAD, Paper.



If you like baseball, *Frog Pond Philosophy* will intrigue you. If you like hunting and fishing, particularly fly fishing, *Frog Pond Philosophy* will appeal to you. If you like thinking about the natural world and how we relate to it, *Frog Pond Philosophy* will interest you.

If you like music, sitting by the water in springtime, and listening to frog song, *Frog Pond Philosophy* will be certain to charm you—particularly the essay that inspires the title of the book. It was one of my favourite pieces in this collection of writings by the late Strachan Donnelley (1942–2008), an environmental philosopher and bioethicist who focussed on studying the intricacies of human-nature relations.

Donnelley was also the founder and first president of the Center for Humans and Nature (https://www.humansandnature.org), an initiative which portrays itself as exploring and promoting human responsibilities in relation to nature and the whole community of life. The Center's website describes Donnelley as rejecting reductionist, silo thinking, and bringing together ideas from many corners, including biology, ecology, economics, engineering, poetry, the arts, and philosophy. This breadth of perspectives is reflected in the subject matter of *Frog Pond Philosophy* essays, which span over four decades of work, and range from hard-core philosophical interpretations to reminiscences on personal encounters and outdoor experiences.

No wonder it took the editors—daughter Ceara Donnelley and colleague Bruce Jennings—so many years to publish the book. It is clearly a labour of love and respect. As Ceara explains in the Editor's Afterword, her father spent the final months of his life re-reading, mulling over, and assembling the manuscript from new and previously published pieces. Shaping the final collection was obviously a task that could not be hurried.

The editors organized the essays into four sections. The first two are introductory and more generally reflective; the last two are more intensely philosophical. The pieces vary in length, many of them short.

The content of the first two sections, aptly named Two Preludes and A Guide for the Naturally Perplexed, was the most compelling, and the essays were easy to read and comprehend. Frog Pond Philosophy was my favourite essay—partly because I love frog song and partly because the content lines were simple. The image of *Homo sapiens* singing alongside innumerable other organisms in a great planetary frog pond adds to the essay's appeal, along with the closing paragraph of the essay where Donnelley calls for insight from "bullfrog philosophers" in the "urgent business" of saving "our earthly frog pond" (p. 35). In the essay Bottom Lines and the Earth's Future, he describes the similarly urgent business of replacing the prevailing economic bottom line with an ecological "nature alive" (p. 51) bottom line—another important message in the current global context of biodiversity loss and climate instability.

The intensely philosophical essays in the final two sections of the book delve into diverse philosophical traditions. Connelly revisits them from different angles with the purpose, in the words of Jennings, of "thinking 'humans' and 'nature' together" (p. 219) and overcoming the separation of "human being" from "the rest of natural being" (p. 220) encouraged by dominant modern philosophical and scientific theory. I confess that I was less motivated to read those pieces thoroughly. I was easily discouraged from wading through them in detail because of their denseness and complexity. But you might not be.

The baseball and fly-fishing analogies introduced early in the book did not, unfortunately, resonate with me. They had, in fact, the opposite effect of alienation, and the feeling did not dissipate easily. But that might not happen to you.

I was pleased to learn that proceeds from the sale of *Frog Pond Philosophy* are being donated by the University Press of Kentucky to the Center for Humans and Nature. That fact, along with the essays in the first two sections of the book, and the second if you are so inclined, would make it worth the purchase.

RENATE SANDER-REGIER
Environmental Studies, University of Ottawa,
Ottawa, ON, Canada

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NEW TITLES

Prepared by Barry Cottam

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Biology of Plant Volatiles. Second Edition. By Eran Pichersky and Natalia Dudareva. 2020. CRC Press. 408 pages, 140.00 USD, Cloth.

The Call of Carnivores: Travels of a Field Biologist. By Hans Kruuk. 2019. Pelagic Publishing. 200 pages, 176 colour illustrations, and 55 drawings, 33.73 CAD, Paper.

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Mosses of the Northern Forest: A Photographic Guide. The Northern Forest Atlas Guides Series. By Jerry Jenkins. 2020. Cornell University Press, Comstock Publishing Associates. 176 pages, 1435 colour photos, and 1321 diagrams, 16.95 USD, Paper, 11.95, USD, Fold-out Chart.

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ENTOMOLOGY

***Butterflies: Their Natural History and Diversity. Second Edition**. By Ronald Orenstein. Photography by Thomas Marent. 2020. Firefly Books. 224 pages, 24.95 CAD / USD, Paper.

Courtship and Mating in Butterflies. By R.J. Cannon. 2020. CABI. 384 pages, 135.00 USD, Cloth.

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Nature Underfoot: Living with Beetles, Crabgrass, Fruit Flies, and Other Tiny Life Around Us. By John Hainze. Illustrated by Angela Mele. 2020. Yale University Press. 254 pages, 28.00 USD, Cloth.

Extraordinary Insects: Weird. Wonderful. Indispensable. The Ones Who Run Our World. By Anne Sverdrup-Thygeson. 2019. HarperCollins, Mudlark Imprint. 320 pages, 14.99 GBP, Cloth, 9.99 GBP, Paper, 5.99 GBP, E-book.

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ORNITHOLOGY

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ZOOLOGY

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†**A Sand County Almanac** and **Sketches Here and There**. By Aldo Leopold. Introduction by Barbara Kingsolver. 2020. Oxford University Press. 240 pages, 15.95 CAD, Paper.

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Our Wild Calling: How Connecting with Animals Can Transform Our Lives—and Save Theirs. By Richard Louv. 2019. Algonquin Books. 320 pages, 37.95 CAD, Cloth.

Phylogenetic Ecology: A History, Critique, and Remodeling. By Nathan G. Swenson. 2020. University of California Press. 240 pages, 120.00 USD, Cloth, 40.00 USD, Paper. Also available as an E-book.

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Re-Bisoning the West: Restoring an American Icon to the Landscape. By Kurt Repanshek. 2019. Torrey House Press. 200 pages, 18.95 USD, Paper.

The Salmon Way: An Alaska State of Mind. 2019. By Amy Gulick. Braided River. 192 pages, 29.95 USD, Cloth.

The Canadian Field-Naturalist

News and Comment

Compiled by Amanda E. Martin

Upcoming Meetings and Workshops

This will be an unusual Upcoming Meetings and Workshops entry. That seems appropriate, given the unusual times in which we find ourselves living. At the time of writing, the novel coronavirus disease, COVID-19, has been detected in most countries, with 1 699 595 confirmed cases and 106 138 fatalities (World Health Organization 2020). In response to this threat, many countries have enacted measures to slow the spread of the virus and to avoid overwhelming our healthcare systems. This includes measures to limit non-essential travel and in-person gatherings. This has led to some events being cancelled (e.g., American Society for Mammalogists annual meeting; https://mammalmeetings.org/) or delayed (e.g., Québec RE^3 Conference; http://www.re3-quebec2020.org/). Others have quickly changed the format of their event, from in-person to online (see listings below). As the COVID-19 situation continues to evolve, we expect that the situation for meeting and workshop organizers will too. Thus, we encourage readers to refer to the meeting/workshop webpages for the most up-to-date information. We wish our readers, their colleagues, friends, and family the best of health during these difficult times.

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Ontario Ecology, Ethology, and Evolution Colloquium

The Ontario Ecology, Ethology, and Evolution Colloquium to be held as an online meeting, 9 May 2020. More information is available at https://oe3c.com/.

North American Regional Association of the International Association for Landscape Ecology Annual Meeting

The annual meeting of the North American Regional Association of the International Association for Landscape Ecology to be held as an online meeting, 11–14 May 2020. Registration is currently open. More information is available at http://www.ialena.org/annual-meeting.html.

Canadian Botanical Association/L'Association Botanique du Canada Annual Meeting

The annual meeting of the Canadian Botanical Association/L'Association Botanique du Canada to be held as an online meeting, 1–2 June 2020. More information is available at https://abc-cba2020.uqat.ca/index.php.

Botany 2020

Botany 2020 to be held 18–22 July 2020 at the Dena'ina Center, Anchorage, Alaska. Registration is currently open. More information is available at http://2020.botanyconference.org/.

Mycological Society of America Annual Meeting

The annual meeting of the Mycological Society of America to be held 19–22 July 2020 at the University of Florida, Gainesville, Florida. The theme of the conference is: 'Mycology in the Swamp'. Registration is currently open. More information is available at https://msafungi.org/2020-annual-meeting/.

North American Congress for Conservation Biology

The 5th biennial North American Congress for Conservation Biology to be held 26–31 July 2020 at the Sheraton Downtown Hotel, Denver, Colorado. The theme of the conference is: 'Crossing Boundaries: Innovative Approaches to Conservation'. Registration is currently open. More information is available at https://scbnorthamerica.org/index.php/naccb-2020/.

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